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J. M. Ellsworth

TEXT-BOOK OF ANATOMY.

SECTION II.

SECTION II.

THE MUSCULAR SYSTEM.

THE NERVOUS SYSTEM.

THE ORGANS OF SENSE AND THE INTEGUMENT.

TEXT-BOOK

OF

ANATOMY

SECTION II.

EDITED BY

D. J. CUNNINGHAM, F.R.S.

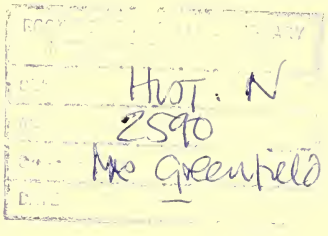
M.D. (EDIN. ET DUBL.), D.SC., LL.D. (GLASG. ET ST. AND.), D.C.L. (OXON.)
PROFESSOR OF ANATOMY, UNIVERSITY OF EDINBURGH

ILLUSTRATED WITH 366 WOOD ENGRAVINGS FROM ORIGINAL DRAWINGS, MOSTLY PRINTED IN COLOURS

SECOND AND THOROUGHLY REVISED EDITION

EDINBURGH, GLASGOW, AND LONDON
HENRY FROWDE AND HODDER & STOUGHTON
1906

Printed by R. & R. Clark, Limited, *Edinburgh.*


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TO

Sir William Turner, K.C.B.

F.R.S., M.B., LL.D., D.C.L., D.SC.,

IN RECOGNITION OF

HIS EMINENCE AS AN ANATOMIST

AND HIS INFLUENCE AS A TEACHER

THIS VOLUME

IS DEDICATED

BY THOSE OF HIS FORMER PUPILS AND ASSISTANTS

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LIST OF CONTRIBUTORS TO SECTION II.

D. J. CUNNINGHAM, M.D., F.R.S.,
Professor of Anatomy, University of Edinburgh.
(*The Brain and Spinal Cord.*)

ROBERT HOWDEN, M.A., M.B.,
Professor of Anatomy, University of Durham.
(*The Organs of Sense and the Integument.*)

A. M. PATERSON, M.D.,
Professor of Anatomy, University College, Liverpool.
(*Myology, The Spinal and Cranial Nerves, The Sympathetic Nervous System.*)

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THE MUSCULAR SYSTEM, &c.

THE MUSCULAR SYSTEM.

MYOLOGY.

By A. M. Paterson.

The movements of the various parts and organs of the body are brought about by the agency of muscle-cells, which are characterised by a special histological structure and by the special function of contracting in length under the influence of a proper stimulus.

There are three classes of muscle-cells: (1) the striated, and usually voluntary muscle-cells, out of which the skeletal muscular system is constructed; (2) the non-striated, involuntary muscle-cells, occurring in the walls of vessels and hollow viscera, etc.; and (3) the cardial muscle-cells, striated but involuntary, of which the substance of the heart is composed.

The following section deals solely with the skeletal muscles, the structure, arrangement, and mechanical action of which are based upon a common plan.

The cells of which the skeletal muscles are composed are long, narrow, and characterised by a peculiar striation, which is different from the striation of the muscle-cells of the heart; they also differ both in structure and function from the non-striated muscle-cells which occur in viscera and vessels.

A **typical skeletal muscle** consists of a fleshy mass enveloped in a membranous aponeurosis or fascia, and provided at its extremities or borders with membranous or tendinous attachments to bone, cartilage, or fascia.

Each muscle is made up of a number of **fasciculi** or bundles, arranged together in different muscles in different ways, so as to give rise to the particular form of the muscle in question. These fasciculi are connected together by a delicate connective tissue, the **perimysium externum**, continuous externally with the aponeurosis enclosing the muscle.

Each muscular bundle or fasciculus is composed of a number of narrow, elongated **muscle-cells** or fibres, held together by a still more delicate connective tissue, the **perimysium internum.** This tissue is connected on the one hand with the **sarcolemma** or cell-wall of the muscle-cell, and on the other hand with the coarser tissue of the perimysium externum enclosing the muscular bundles.

By means of these connective tissue envelopes the muscle-cells, the essential agents of motor activity, are brought into firm and intimate relation with the osseous or other attachments of the muscle. Through the agency of sarcolemma, perimysium internum, perimysium externum, aponeurosis, and tendon, the muscle-cell when it contracts can produce a precise and definite effect upon the weight to be moved.

Each muscle is supplied by one or more nerves, which, in their course through the muscle, separate into smaller and smaller branches, ultimately, by their terminal filaments (axons), forming special end-organs in relation to each muscle-cell.

While a muscle may thus be looked upon as an organ endowed with particular properties, and executing a definite movement in response to a stimulus by the simultaneous contraction of its constituent cells, the various muscles may further be considered in groups, associated together by mode of development, nerve-supply, and co-ordination of action. For example, we speak of the hamstring muscles of

the thigh, the muscles of the back, and the prævertebral muscles—groups in which separate muscles are associated together by development, nerve-supply, and action. In their development the separate muscles arise from the subdivision of a larger stratum, as in the limbs, or from the fusion of segmental elements (myotomes), as in the case of the axial muscles; the peripheral nerves supplying skeletal muscles are distributed, through the plexuses or directly, so as to associate particular muscles morphologically and physiologically, and to secure a co-ordinated movement by the simultaneous contraction of several muscles together.

FASCIÆ.

Beneath the skin there are two (or in some regions three) layers of tissue which require consideration: the superficial fascia (panniculus adiposus), the deep fascia (fascia lata), and, in animals, the panniculus carnosus (rudimentary in man, and represented chiefly by the *platysma myoides* in the neck).

Superficial Fascia.—The superficial fascia is a continuous sheet of areolar tissue which underlies the skin of the whole body. It is closely adherent to the cutis vera, and is sometimes termed **panniculus adiposus**, from the fact that, except beneath the skin of the eyelids, penis, and scrotum, it is always more or less impregnated with fat. It is traversed by the cutaneous vessels and nerves; and its deep surface, membranous in character, is in loose connexion with the subjacent deep fascia. It is in this layer that dropsical effusions chiefly occur.

Deep Fascia.—Underneath the skin and superficial fascia is a fibrous membrane, bluish white in colour, devoid of fat, and in closest relation to skeleton, ligaments, and muscles. This is the deep fascia. It covers, invests, and in some cases forms the means of attachment of the various muscles. It has a special tendency to become attached to all subcutaneous bony prominences, and to be continuous with the connecting ligaments. It forms septal processes, which separate groups of muscles and individual muscles; enclose glands and viscera; and form sheaths for vessels and nerves. Around joints it gives rise to bands which strengthen the capsule or limit the mobility of the joint, or, as in the case of annular ligaments, bind down the tendons passing over the joint. It not only ensheathes vessels and nerves, but is perforated by those which pass between superficial and deeper parts.

The term **aponeurosis** is used in relation to muscles. It is synonymous with deep fascia, either as an investing fascia, or as a membranous layer which (*e.g.* vertebral aponeurosis) performs at one and the same time the purpose of a deep fascia and the expanded membranous attachment of a muscle.

The **panniculus carnosus** is a thin muscular layer enveloping the trunk of animals with a hairy or furry coat. It is strongly developed in the hedgehog. In man it is represented mainly in the (rudimentary) platysma myoides. It is placed between the superficial and the deep fascia.

Bursæ.—Where a tendon passes over a bony surface, or where the superficial fascia and skin cover a bony prominence, there is generally formed a synovial sac, or bursa, containing fluid, for the purpose of lubricating the surface over which the tendon or fascia glides. Allied to these are the synovial sheaths which envelop tendons beneath the annular ligaments in relation to the several joints.

Description of Muscles.—In studying the muscular system it is necessary to note the following characters in reference to each individual muscle: (1) The *shape* of the muscle—flat, cylindrical, triangular, rhomboidal, etc.—and the character of its extremities—membranous, tendinous, or fleshy. (2) The *attachments* of the muscle. The *origin* is the more fixed or central attachment: the *insertion* is the more movable or peripheral attachment. (3) The *relations* of the surfaces and borders of the muscle to bones, joints, other muscles, and other important structures. (4) Its *vascular* and *nervous supply*; and (5) *its action.* It must be borne in mind that hardly any single muscle acts alone. Each muscle, as a rule, forms one of a group acting more or less in harmony with, and antagonised by, other and opposite groups.

DESCRIPTION OF THE MUSCLES.

The skeletal muscles may be divided into two series: axial and appendicular. The **axial** muscles comprise the muscles of the trunk, head, and face, including the **panniculus carnosus** (platysma myoides). These muscles are more or less segmental in arrangement, grouped around the axial skeleton. The **appendicular muscles**, the muscles of the limbs, are grouped around the appendicular skeleton. They are not segmental in arrangement, they are clearly separate from the axial muscles, and they are arranged in definite strata in relation to the bones of the limbs.

APPENDICULAR MUSCLES.

THE UPPER LIMB.

FASCIÆ AND SUPERFICIAL MUSCLES OF THE BACK.

Fasciæ.

The **superficial fascia** of the back presents no peculiarity. It is usually of considerable thickness, and contains a quantity of fat.

The **deep fascia** closely invests the muscles. It is attached in the middle line of the back to the ligamentum nuchæ, supraspinous ligaments, and vertebral spines; laterally it is attached to the spine of the scapula and the clavicle, and is continued over the deltoid region to the arm. In the neck it is attached above to the superior curved line of the occipital bone, and is continuous laterally with the deep cervical fascia. Below the level of the arm it is continuous round the border of the latissimus dorsi muscle, with the fascia of the axilla and of the abdominal wall. In the back and loin it constitutes the **vertebral aponeurosis** or aponeurosis of the latissimus dorsi. It conceals the erector spinæ muscle, forming the posterior layer of the **lumbar fascia**, and it is attached internally to the vertebral spines, and externally to the angles of the ribs, to the lumbar fascia, and to the iliac crest.

The Superficial Muscles of the Back.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral; (2) vertebro-costal; (3) vertebro-cranial; and (4) vertebral. The first of this series consists of the posterior muscles connecting the upper limb to the trunk, and comprises the first two layers of the muscles of the back—(1) trapezius and latissimus dorsi, and (2) levator anguli scapulæ and rhomboidei (major and minor). The deeper (axial) muscles of the back are dealt with later.

The **trapezius** (m. trapezius, cucullaris) is a large triangular muscle occupying the upper part of the back. It **arises** from the superior curved line of the occipital bone in its inner third, from the external occipital protuberance (Fig. 312, p. 397), from the ligamentum nuchæ, from the spines of the seventh cervical and all the thoracic vertebræ, and the corresponding supra-spinous ligaments. The origin is by direct fleshy attachment, except in relation to the occipital bone, the lower part of the neck, and the lower thoracic vertebræ, in which places the origins are tendinous. From their origin the muscular fibres converge towards the bones of the shoulder, to be **inserted** continuously from before backwards as follows: (1) The occipital and upper cervical fibres—into the posterior surface of the clavicle in its outer third (Figs. 243, p. 319, and 248, p. 324); (2) the lower cervical and upper thoracic fibres—into the inner border of the acromion process, and the upper border of the spine of the scapula; and (3) the lower thoracic fibres, by a triangular flat tendon, beneath which a bursa is placed—into a rough tuberosity at the base of the spine of the scapula ~~(Fig. 299, p. 383).~~ The fibres inserted into the clavicle, acromion, and the upper border of the spine of the scapula, spread over the adjacent subcutaneous surfaces of these bones for a variable distance.

The occipital portion of the muscle may be in the form of a separate slip, or may be entirely absent.

The trapezius is superficial in its whole extent. Its upper lateral border forms the posterior limit of the posterior triangle of the neck. The lower lateral border, passing over the upper edge of the latissimus dorsi and the vertebral border of the scapula, forms a boundary of the so-called *triangle of auscultation* completed below by the latissimus dorsi, and externally by the vertebral border of the scapula. This space is partly filled up by the rhomboideus major. The deep surface of the muscle is in contact with the complexus, splenius capitis, omohyoid, supraspinatus, levator anguli scapulæ, rhomboidei, serratus posticus superior, erector spinæ, and latissimus dorsi muscles. The spinal accessory nerve, branches of the cervical plexus (C. 3. 4.), and of the superficial cervical and posterior scapular arteries, are situated beneath the muscle.

The **latissimus dorsi** is a large triangular muscle occupying the lower part of the back. It has a triple origin. The greater part of the muscle **arises**—(1) from

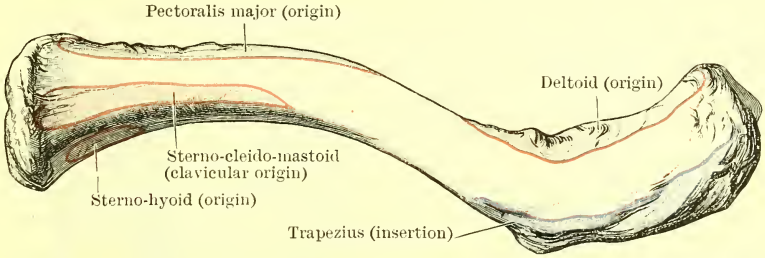


Fig. 243.—Muscle-Attachments to the Clavicle (Upper Surface).

the *vertebral aponeurosis* (posterior layer of the lumbar fascia or aponeurosis of the latissimus dorsi). This is a thick membrane which conceals the erector spinæ in the lower part of the back. Through it the latissimus dorsi gains attachment to the spines of the lower six thoracic vertebræ, the spines of the lumbar vertebræ, and the tendon of the erector spinæ with which the aponeurosis blends below. It also arises more externally by fleshy fibres from the posterior part of the iliac crest. From this origin the muscle is directed upwards and outwards, its fibres converging to the lower angle of the scapula. In relation to its upper and outer borders additional fibres arise. (2) *Along the outer border* muscular slips arise from the lower three or four ribs, inter-digitating with the origins of the obliquus externus abdominis. (3) As *the upper border* of the muscle passes horizontally over the lower angle of the scapula, an additional fleshy slip usually takes origin from this part of the bone to join the muscle on its deep surface (Fig. 245, p. 321).

Beyond the lower angle of the scapula the latissimus dorsi, greatly narrowed, curves spirally round the teres major muscle, and forms the prominence of the posterior axillary fold. It ends in a ribbon-like tendon, closely adherent at first to the teres major, which is **inserted** into the floor of the bicipital groove of the humerus, extending for about three inches below the lower and outer part of the lesser tuberosity (Fig. 253, p. 329). It is placed behind the coraco-brachialis and biceps, and the axillary vessels and nerves, and in front of the insertion of the teres major, from which it is separated by a bursa.

In the back the latissimus dorsi is superficial, except in its upper part, which is concealed by the trapezius. It lies upon the lumbar fascia, serratus posticus inferior, the ribs, and lower angle of the scapula, and at its borders two triangular spaces are formed; at the upper border is the so-called *triangle of auscultation*; at the outer border is the *triangle of Petit*, a small space bounded by the iliac crest, the latissimus dorsi, and the obliquus externus abdominis. This is the site of an occasional lumbar hernia.

The **levator anguli scapulæ** (levator scapulæ) is a strap-like muscle, **arising** by tendinous slips from the posterior tubercles of the transverse processes of the first three or four cervical vertebræ, between the attachments of the scalenus medius in front and the splenius colli behind. It is directed downwards along the

side of the neck, to be **inserted** into the vertebral border of the scapula in its upper fourth, from the superior angle to the spine (Fig. 245, p. 321). It is concealed in its upper third by the sterno-mastoid and deep muscles of the neck. In its middle third it occupies the floor of the posterior triangle. In its lower third it is again

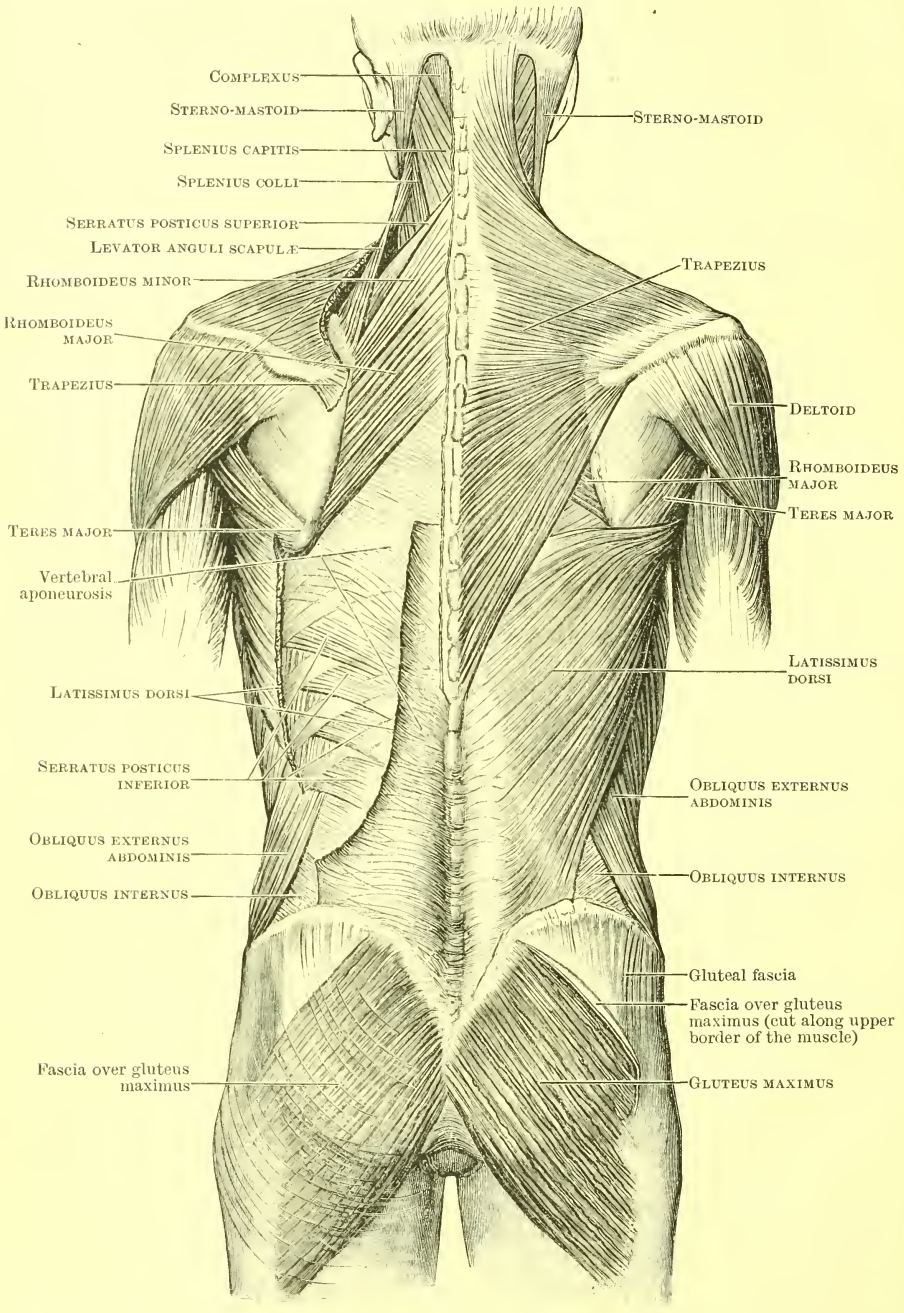


Fig. 244.—Superficial Muscles of the Back.

hidden from view by the trapezius. It conceals the splenius colli and cervicalis ascendens muscles.

The **rhomboideus minor** may be regarded as a separated slip of the rhomboideus major, with which it is often continuous. It **arises** from the *ligamentum nuchæ* and the spines of the seventh cervical and first thoracic vertebræ. Passing obliquely downwards and outwards, it is **inserted** into the vertebral border of the

scapula below the levator anguli scapulæ muscle, and opposite to the base of the spine (Fig. 245, p. 321).

The **rhomboideus major arises** from the spinous processes of the thoracic vertebræ from the second to the fifth inclusive, and from the corresponding supraspinous ligaments. Passing downwards and outwards, it is **inserted** below the rhomboideus minor into the vertebral border of the scapula, between the spine and the lower angle (Fig. 245, p. 321). The muscle is only inserted directly into the scapula by means of its lower fibres. Its upper part is attached to a membranous band, which, connected for the most part by loose areolar tissue to the vertebral border of the scapula, is fixed to the bone at its extremities, above near the base of the spine, and below at the inferior angle.

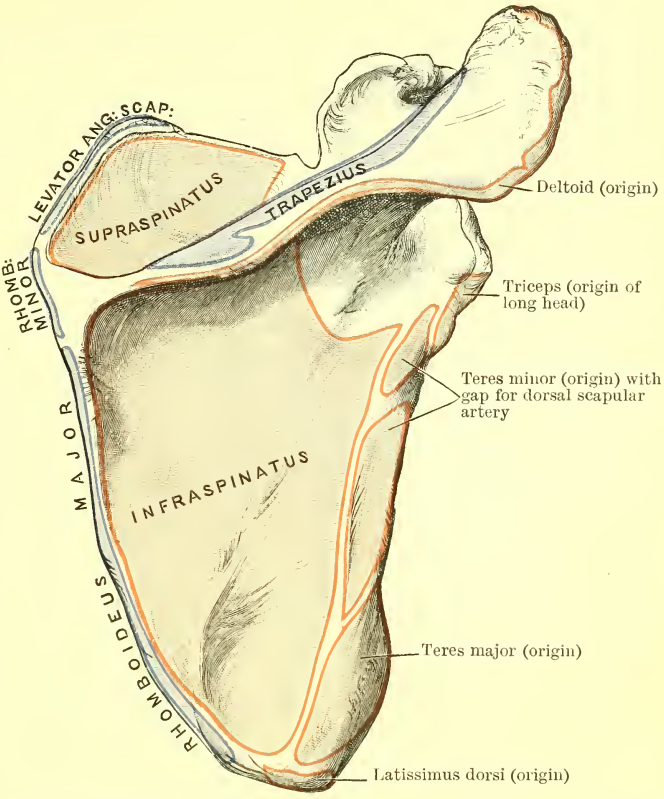


FIG. 245.—MUSCLE-ATTACHMENTS TO THE SCAPULA (Posterior Surface).

The rhomboid muscles are concealed for the most part by the trapezius. The lower part of the rhomboideus major is superficial in the *triangle of auscultation*. The muscles cover the serratus posticus superior and vertebral aponeurosis.

THE FASCIÆ AND MUSCLES OF THE PECTORAL REGION.

FASCIÆ.

The **superficial fascia** of the chest usually contains a quantity of fat, in which the mamma is embedded. The origin of the platysma myoides muscle lies beneath its upper part.

The **deep fascia** is attached above to the clavicle, and internally to the sternum. Below it is continuous with the fascia of the abdominal wall. It gives origin to the platysma myoides, and invests the pectoralis major. At the outer border of the great pectoral muscle it is thickened, and forms the floor of the axillary space **(axillary fascia)**, continued posteriorly on to the posterior fold of the axilla (teres major and latissmus dorsi), and externally into connexion with the deep fascia of the arm.

Costo-Coracoid Membrane.—Beneath the pectoralis major a deeper stratum of fascia invests the pectoralis minor muscle. At the upper border of this muscle it forms the costo-coracoid membrane, which passes upwards to the lower border of the subclavius muscle, where it splits into two layers, attached in front of and behind that muscle to the borders of the under surface of the clavicle. The membrane traced inwards along the subclavius muscle is attached to the first costal cartilage; passing outwards along the upper border of the pectoralis minor it reaches the coracoid process. The part of the membrane extending directly between the first

costal cartilage and the coracoid process is thickened and forms the **costo-coracoid ligament**. The costo-coracoid membrane is otherwise thin and of comparatively small importance. It is pierced by the cephalic vein, thoracic axis artery and vein, and branches of the external anterior thoracic nerve. By its deep surface it is connected to the sheath of the axillary vessels.

At the lower border of the pectoralis minor there is a further extension of the deep fascia beneath the pectoralis major. It passes downwards to join the fascia forming the floor of the axilla, and is continued externally into the fascia covering the biceps and coraco-brachialis muscles.

MUSCLES OF THE PECTORAL REGION.

The anterior muscles connecting the upper limb to the axial skeleton comprise the pectoralis major, pectoralis minor, subclavius, serratus magnus, and sterno-cleido-mastoid. The last is described in a later section.

The **pectoralis major** is a large fan-shaped muscle **arising** in three parts: (1) *a clavicular portion* arising from the front of the clavicle in its inner half or two-thirds (Figs. 248, p. 324, and 243, p. 319); (2) *a costo-sternal portion*, the largest part of the muscle, arising from the anterior surface of the pre-sternum and meso-sternum by tendinous fibres decussating with those of the opposite muscle (Fig. 246, p. 322); and more deeply from the cartilages of the first six ribs; (3) *an abdominal portion*, a small and separate slip, arising from the aponeurosis of the obliquus externus muscle. The abdominal slip, at first separate, soon merges with the costo-sternal portion, but a distinct interval usually remains between the two first-named parts of the muscle. The fibres converge towards the upper part of the arm, and are inseparably blended at a point half an inch from their insertion into the humerus. The muscle is **inserted** into (1) the outer border of the bicipital groove of the humerus, extending upwards to the great tuberosity, and blending externally with the insertion of the deltoid, internally with the insertion of the latissimus dorsi (Fig. 253, p. 329); (2) from the upper border of the insertion a membranous band extends upwards to the capsule of the shoulder-joint, enveloping at the same time the tendon of the biceps; and (3) from the lower border a band of fascia passes downwards to join the fascia of the arm.

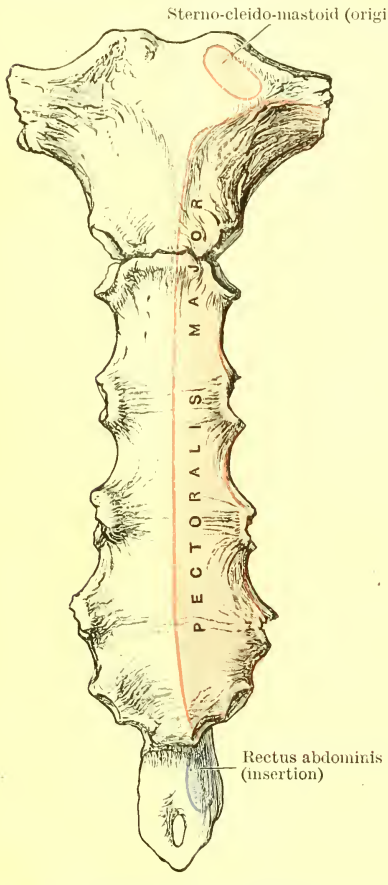


FIG. 246.—MUSCLE-ATTACHMENTS TO THE FRONT OF THE STERNUM.

The arrangement of the fibres of the muscle at its insertion is peculiar. The muscle is twisted on itself, so that the lower (*costo-sternal*) fibres are directed upwards and outwards behind the upper (*clavicular*) part of the muscle; in consequence the clavicular part is attached to the humerus lower down than the costo-sternal portion, and is inserted also into the fascia of the arm. The twisting of the fibres is specially found in the lower costo-sternal fibres of the muscle and the abdominal fibres. These curve upwards behind the upper costo-sternal fibres, and are inserted highest to the shaft of the humerus, helping to form the fascial expansion which extends upwards over the biceps tendon to the capsule of the shoulder-joint. In this way a bilaminar tendon is produced united

along its lower border; and consisting of a superficial lamina formed by the upper costo-sternal fibres, blending for the most part with the tendon of the clavicular portion; and a deep lamina, composed of the twisted lower costo-sternal and abdominal fibres. The disposition of the muscular fibres at their insertions is the

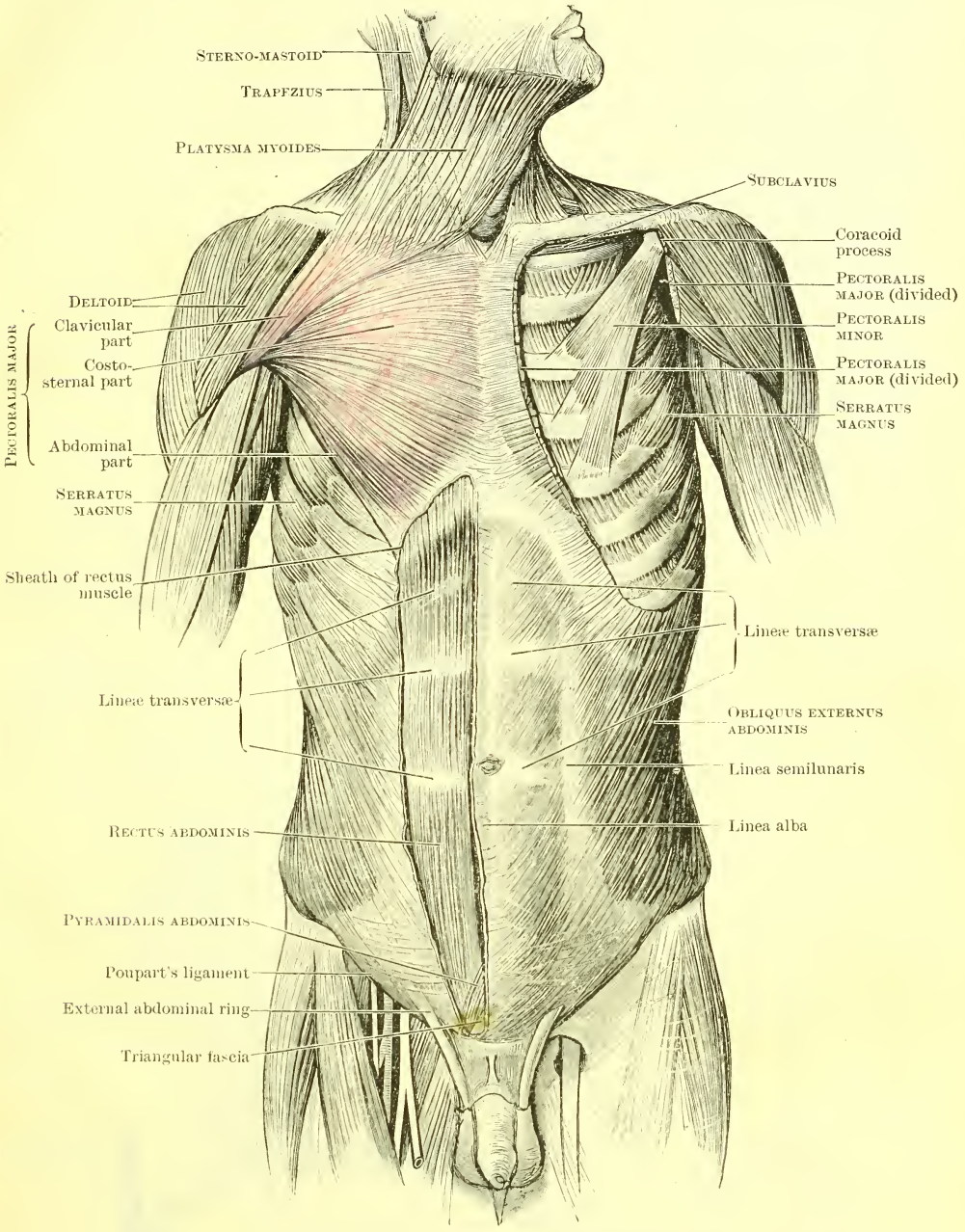


Fig. 247.—Anterior Muscles of the Trunk.

reason for the application of the terms *portio attollens* to the clavicular portion, and *portio deprimens* to the costo-sternal and abdominal portions of the muscle.

Placed superficially on the chest wall, the pectoralis major forms the front wall of the axilla, and by its lower or outer border, the anterior fold of the space. Its upper border is separated from the edge of the deltoid muscle by an interval in which lie the cephalic vein and humeral artery. Its deep surface is in relation with the ribs and intercostal muscles, the costo-coracoid membrane and

the structures piercing it, the pectoralis minor, the axillary vessels, and the nerves of the brachial plexus.

Sternalis muscle.—The sternalis is an occasional muscle placed, when present, parallel to the sternum upon the sterno-costal origin of the pectoralis major. It has attachments which are very variable both above and below, to the costal cartilages, sternum, rectus sheath, sterno-mastoid, and pectoralis major. Its **nerve-supply** is from one or both of the anterior thoracic nerves. In certain rare cases it has been said to be innervated by intercostal nerves. It is present in 4·4 cases out of 100, and it is slightly more frequent in the male than in the female. It has been regarded by different observers as (1) a vestige of the panniculus carnosus, (2) a homologue of the sterno-mastoid, or (3) a displaced slip of the pectoralis major.

Chondro-epitrochlearis, dorso-epitrochlearis, axillary arches, costo-coracoideus.—One or other of the above-named slips is occasionally present, crossing the floor of the axilla in the interval between the latissimus dorsi and the pectoralis major. They take **origin** from the costal cartilages, ribs, or borders of the pectoralis major (*chondro-epitrochlearis, axillary arches, costo-coracoideus*), or from the border of the latissimus dorsi (*dorso-epitrochlearis, axillary arches, costo-coracoideus*). Their **insertion** is variable. The *chondro-epitrochlearis* and *dorso-epitrochlearis* are inserted into the fascia of the arm on the inner side, the internal intermuscular septum, or the internal condyle of the humerus. The *axillary arches* are inserted into the border of the pectoralis major, the fascia of the arm, or the coraco-brachialis or biceps muscle. The *costo-coracoideus*, arising from the ribs or the aponeurosis of the obliquus externus, or detaching itself from the border of the pectoralis major or latissimus dorsi, is attached to the coracoid process, alone or along with one of the muscles attached to that bone. These variable slips of muscle are supplied by the internal anterior thoracic nerve, the lesser internal cutaneous nerve, or the intercosto-humeral.

The **pectoralis minor** is a narrow, flat, triangular muscle. It **arises** from (1) the outer surfaces and upper borders of the third, fourth, and fifth ribs near their anterior ends, and (2) from the fascia covering the third and fourth intercostal spaces between these ribs. It may have an additional origin from the second rib (Fig. 330, p. 420); and that from the fifth rib is often absent. Directed obliquely outwards and upwards, it is **inserted** by a short, flat tendon into the outer half of the anterior (inner) border and upper surface of the coracoid process (Fig. 250, p. 325), and usually also into the conjoint origin of the biceps and coraco-brachialis. It is wholly concealed by the pectoralis major, except when the arm is raised, when the outer border of the muscle becomes superficial. It enters into the formation of the front wall of the axilla, and gives attachment along its upper border to the costo-coracoid membrane. It crosses the axillary vessels and the cords of the brachial plexus, and is pierced by branches of the anterior thoracic nerves.

Either in part or wholly the pectoralis minor may pass over the coracoid process of the scapula, separated from it by a bursa, to be inserted into the coraco-acromial ligament, or the acromion process; or piercing the coraco-acromial ligament, it may be attached to the capsule of the shoulder-joint (coraco-humeral ligament).

Pectoralis minimus.—This is a slender slip, rarely present, which extends between the first costal cartilage and the coracoid process.

The **subclavius muscle arises** from the upper surface of the first costal cartilage in front of the costo-clavicular ligament, and from the upper surface of the

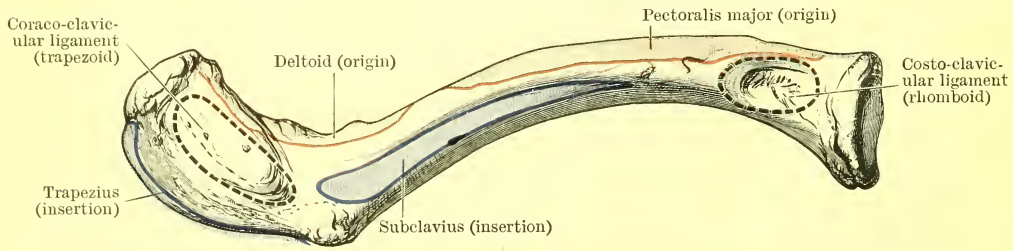


FIG. 248.—MUSCLE-ATTACHMENTS TO THE CLAVICLE (Under Surface).

distal end of the first rib (Fig. 330, p. 420). It is **inserted** into a groove in the middle third of the under surface of the clavicle (Fig. 248, p. 324). The muscle is invested by the fascia which forms the costo-coracoid membrane, and is concealed by the clavicle and the clavicular origin of the pectoralis major.

The **sterno-clavicularis** is a small separate slip, rarely present, extending beneath the pectoralis major from the upper part of the sternum to the clavicle.

The **serratus magnus** (m. serratus anterior) is a large curved quadrilateral muscle occupying the side of the chest and inner wall of the axilla. It **arises** by fleshy slips from the external aspect of the upper eight and occasionally (as in the figure) from nine ribs. The first slip is a double one, arising from the first two ribs and the fascia covering the intervening space (Fig. 330, p. 420). The **insertion** of the muscle is threefold. (1) The first portion of the muscle (from the first and second ribs) is directed backwards to be inserted into the ventral aspect of the upper angle of the scapula. (2) The next three slips of the muscle (from the second, third, and fourth ribs) are inserted into the vertebral border of the scapula. (3) The last four slips (from the fifth, sixth, seventh, and eighth ribs) are directed obliquely upwards and backwards, to be inserted on the ventral aspect of the lower angle of the scapula (Fig. 250, p. 325).

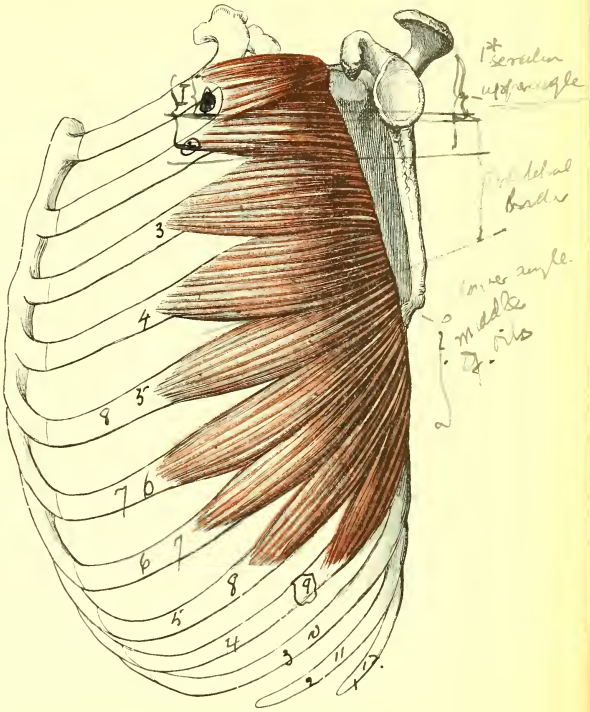


Fig. 249.—The Serratus Magnus Muscle.

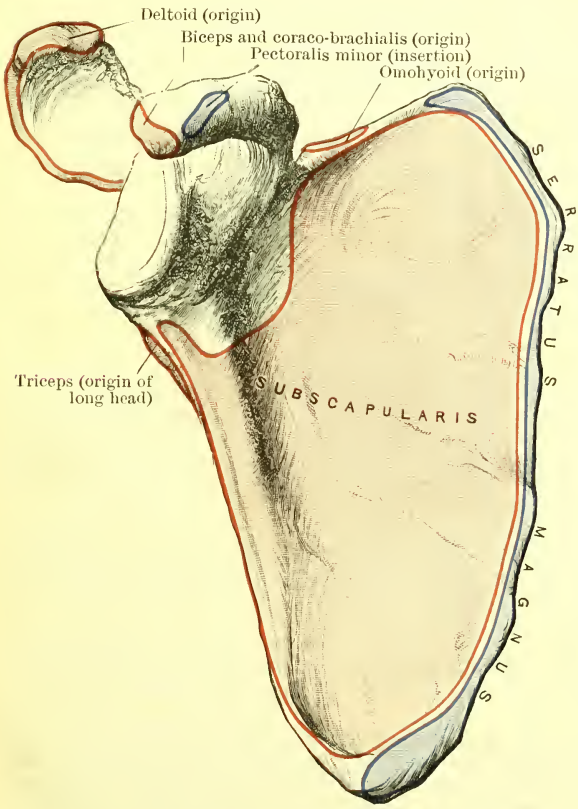


Fig. 250.—Muscle-Attachments to the Scapula (Anterior Aspect).

The external surface of the muscle is partly superficial below the axillary space, on the side wall of the chest, where its slips of origin are seen interdigitating with those of the obliquus externus abdominis. Higher up it forms the inner wall of the axilla, and is in contact with the pectoral muscles in front and the subscapularis behind. Its upper border appears in the floor of the posterior triangle, and over it the axillary artery and the cords of the brachial plexus pass in their course through the armpit. The lower border is oblique, and is in contact with the latissimus dorsi muscle. The deep surface of the muscle is in contact with the chest wall, so that the serratus magnus along with the subscapularis muscle separates the scapula from the ribs. The muscle may extend higher than usual, so as to be continuous in the neck with the levator anguli scapulæ.

Nerve-Supply.

The nerves supplying the muscles connecting the upper limb to the trunk are given in the following table :—

Muscles.	Nerves.	Origin.
Trapezius	Spinal accessory nerve	Spinal Cord
	Cervical plexus	C. 3. 4.
Latissimus dorsi	Long subscapular	C. 6. 7. 8.
Levator scapulæ	Cervical plexus	C. 3. 4.
	Posterior scapular	C. 5.
Rhomboidei	Posterior scapular	C. 5.
Pectorales	External anterior thoracic	C. 5. 6. 7.
	Internal „ „	C. 8. T. 1.
Subclavius	Brachial plexus	C. 5. 6.
Serratus magnus	Posterior thoracic	C. 5. 6. 7.

Actions.

The muscles of this group (together with the sterno-cleido-mastoid and omohyoid muscles) act for the most part in the movements of the shoulder girdle at the sterno-clavicular and acromio-clavicular joints. At the former joint they produce the various movements of the clavicle on the sternum, and cause the shoulder to move in an arc the centre of which is the sterno-clavicular joint. At the acromio-clavicular articulation they produce a rotation of the scapula on the clavicle, and a consequent alteration in the direction of the glenoid fossa. At the same time the several muscles are agents in other equally important movements, when the shoulder girdle is fixed ; movements of the head and neck ; movements of the trunk and ribs ; and, in addition in the case of the pectoralis major and latissimus dorsi, important movements of the arm at the shoulder-joint.

1. Movements of the Shoulder Girdle.—The action of this group of muscles on the shoulder girdle (mainly corresponding to movements at the sterno-clavicular joint) may be expressed in the following table :—

a. **Movement in a Vertical Plane.**		*b.* **Movement in a Horizontal Plane.**	
Elevation.	**Depression.**	**Forwards.**	**Backwards.**
Trapezius (upper fibres)	Trapezius (lower fibres)	Serratus magnus	Trapezius
Levator scapulæ	Subclavius	Pectoralis major	Rhomboidei
Rhomboidei	Pectoralis minor	Pectoralis minor	Latissimus dorsi
Sterno-mastoid	Latissimus dorsi		
Omohyoid	Pectoralis major (lower fibres)		
		c. **Rotation**—a combination of these muscles.	

2. Movements of the scapula on the clavicle produce an alteration of the direction of the glenoid fossa of the scapula, and are accompanied by movements, inwards or outwards, forwards or backwards, of the inferior angle of the scapula. By the combined action of the muscles acting upon the shoulder girdle a **rotatory movement** of the scapula at the acromio-clavicular joint is effected, by which the relation of the glenoid fossa to the head of the humerus is preserved in movements of the arm.

3. In forced inspiration, the sterno-mastoid, trapezius, levator scapulæ, rhomboidei, subclavius, omohyoid, serratus magnus, pectoral muscles, and latissimus dorsi, acting together, raise and fix the shoulder girdle ; while those of them which have costal attachments—subclavius, pectoral muscles, serratus magnus, and latissimus dorsi, simultaneously elevate the ribs and expand the thorax.

4. Lateral flexion and rotation of the spine in the neck is effected partly by the action of the trapezius, levator scapulæ, and rhomboid muscles (with the shoulder fixed). The latissimus dorsi and pectoralis major act in climbing in a similar way, raising up the trunk towards the shoulder.

5. Action on the Upper Limb.—By reason of their insertion into the humerus the pectoralis major and latissimus dorsi muscles assist the movements of the upper limb. Acting together, the two muscles depress the shoulder, and draw the arm to the side of the body, at the same time rotating the humerus inwards. The two parts of the pectoralis major have slightly different actions on the humerus. The clavicular part of the muscle (*portio attollens*) draws the arm inwards and upwards ; the costo-sternal part of the muscle (*portio deprimens*) draws it inwards and downwards. The latissimus dorsi acting alone, besides rotating the limb, draws it inwards and backwards, as in the act of swimming.

FASCIÆ AND MUSCLES OF THE SHOULDER.

The **deep fascia** covering the scapular muscles presents no feature of special importance. Attached to the clavicle, acromion, and scapular spine, it is thin over the deltoid muscle. Below the deltoid it is thicker; it encases and gives origin to the infraspinatus muscle, and is continuous with the fasciæ of the axilla and the back.

Muscles.

The **muscles** proper to the shoulder comprise the deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis. They surround, and along with other muscles, act on the shoulder-joint.

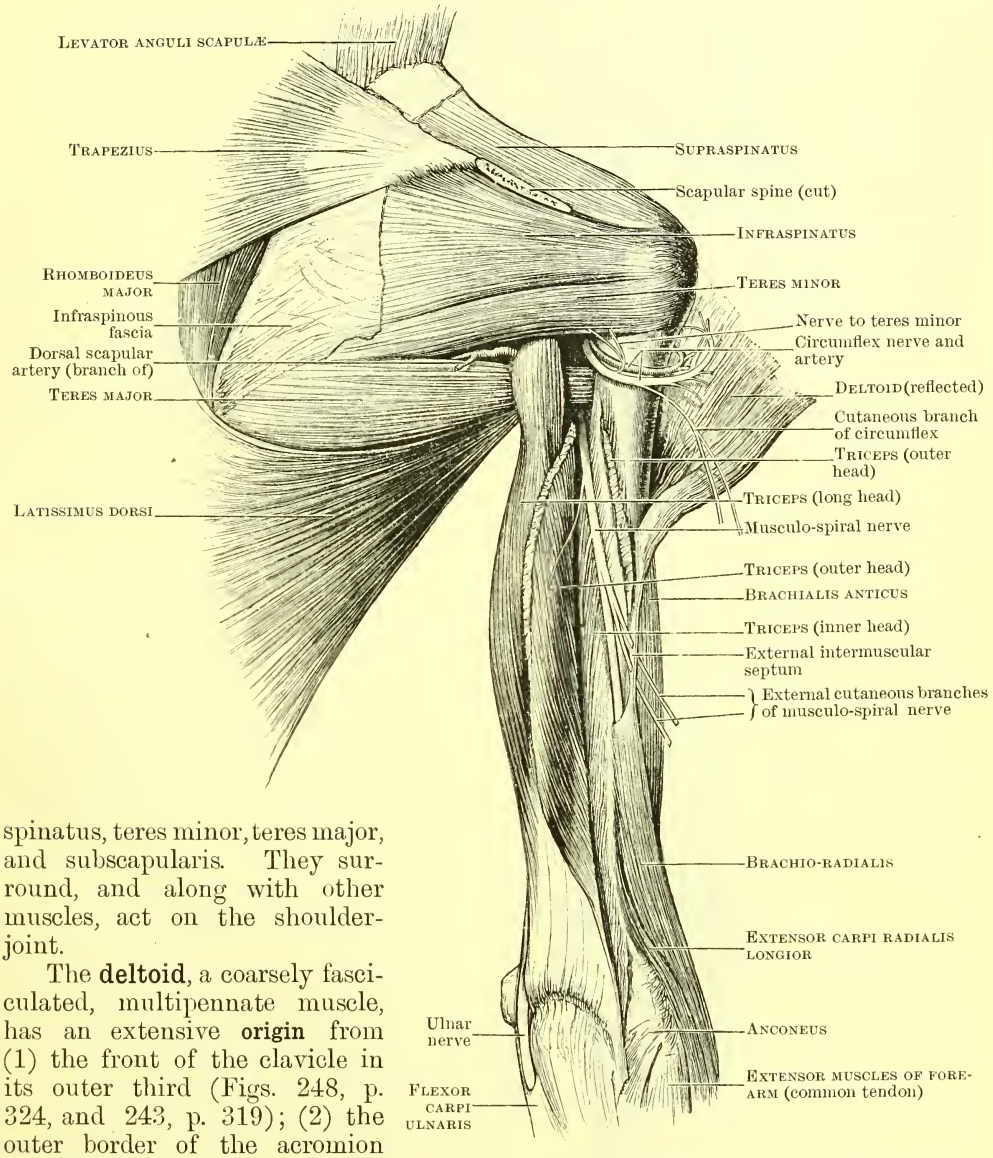


Fig. 251.—Deltoid Region and Back of the Arm.

The **deltoid**, a coarsely fasciculated, multipennate muscle, has an extensive **origin** from (1) the front of the clavicle in its outer third (Figs. 248, p. 324, and 243, p. 319); (2) the outer border of the acromion process; (3) the lower edge of the free border of the spine of the scapula (Figs. 254, p. 330, and 250, p. 325); and (4) from the deep fascia covering the infraspinatus muscle. Its origin embraces the insertion of the trapezius. The fibres of the muscle converge to the outer side of the shaft of the humerus, to be **inserted** into a well-marked V-shaped impression above the spiral groove (Figs. 257 and 258, p. 335). The insertion is partly united with the tendon of the pectoralis major. The deltoid is superficial in its whole extent, and forms the prom-

inence of the shoulder. Its anterior border is separated from the pectoralis major by a narrow interval, in which the cephalic vein and humeral artery are placed. The deep surface of the muscle is separated by a bursa from the capsule of the shoulder-

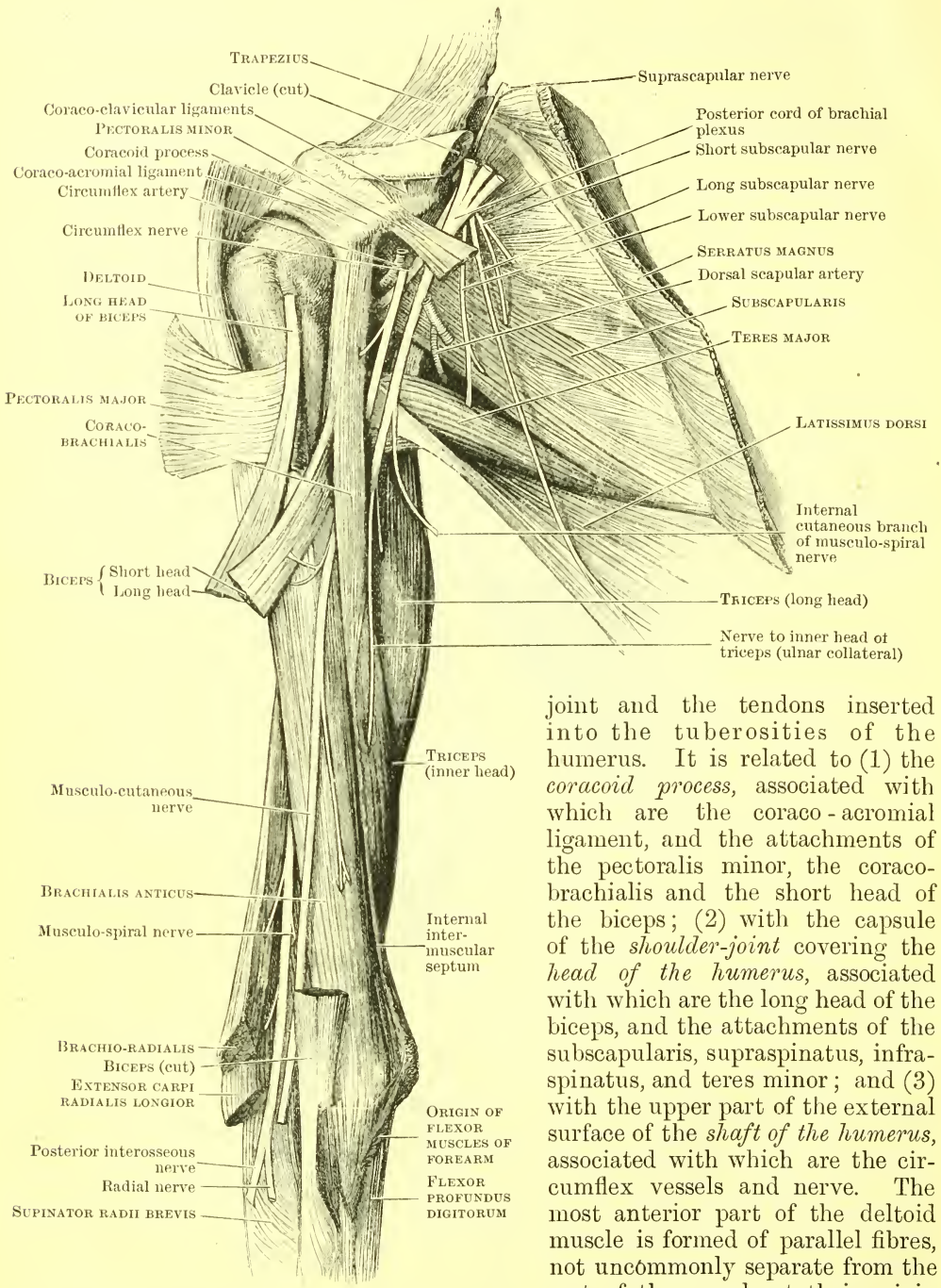


Fig. 252.—The Posterior Wall of the Axilla and the Front of the Arm (the biceps being divided).

joint and the tendons inserted into the tuberosities of the humerus. It is related to (1) the *coracoid process*, associated with which are the coraco-acromial ligament, and the attachments of the pectoralis minor, the coraco-brachialis and the short head of the biceps; (2) with the capsule of the *shoulder-joint* covering the *head of the humerus*, associated with which are the long head of the biceps, and the attachments of the subscapularis, supraspinatus, infraspinatus, and teres minor; and (3) with the upper part of the external surface of the *shaft of the humerus*, associated with which are the circumflex vessels and nerve. The most anterior part of the deltoid muscle is formed of parallel fibres, not uncommonly separate from the rest of the muscle at their origin from the clavicle. These fibres may be continuous with the trapezius over the clavicle. The most posterior part arises by a fascial origin from the spine of the scapula and the fascia over the infraspinatus muscle. These portions are attached respectively to the front and back of the main tendon of insertion. The intermediate fibres are multipennate, attached above and below to three or four

septal tendons, which extend for a variable distance from the origin and insertion of the muscle.

The **supraspinatus** arises by fleshy fibres from the supraspinous fossa (except near the neck of the bone) and from the deep fascia over it (Fig. 254, p. 330). It is directed outwards under the acromion process and coraco-acromial ligament to be **inserted** by a broad thick tendon into the uppermost facet on the great tuberosity of the humerus, and into the capsule of the shoulder-joint (Fig. 253, p. 329).

The muscle is entirely concealed from view by the trapezius, the acromion process, and the deltoid muscle. It covers the neck of the scapula, the suprascapular vessels and nerves, and the upper surface of the capsule of the shoulder-joint.

The **infraspinatus** arises from the infraspinous fossa of the scapula (excepting near the neck of the bone and the flat surface along the axillary border) and from the thick fascia over it (Fig. 254, p. 330). The fibres of the muscle converge to the neck of the scapula; and are **inserted** by tendon into the middle facet on the great tuberosity of the humerus, and into the capsule of the shoulder-joint (Fig. 258, p. 335). A bursa separates the muscle from the neck of the scapula, and in a minority of cases communicates with the synovial cavity of the shoulder-joint.

The upper part of the muscle is hidden from view by the deltoid. Its lower part is superficial, and its outer border is in contact with the teres minor. Near its insertion it crosses the neck of the scapula and the back of the capsule of the shoulder-joint.

The **teres minor** is a small muscle, **arising** by fleshy fibres from the upper two-thirds of the flat surface on the dorsal aspect of the axillary border of the scapula, and from fascial septa separating it from the infraspinatus and teres major muscles (Fig. 254, p. 330). Lying alongside the outer border of the infraspinatus, it is **inserted** under cover of the deltoid by a thick flat tendon into the lowest of the three facets on the great tuberosity of the humerus and into the capsule of the shoulder-joint, and by fleshy fibres into the posterior aspect of the surgical neck and shaft of the humerus, below the tuberosity for about an inch (Fig. 258, p. 335). It is separated from the teres major by the scapular head of the triceps, and by the posterior circumflex vessels and the circumflex nerve. Its origin is pierced by

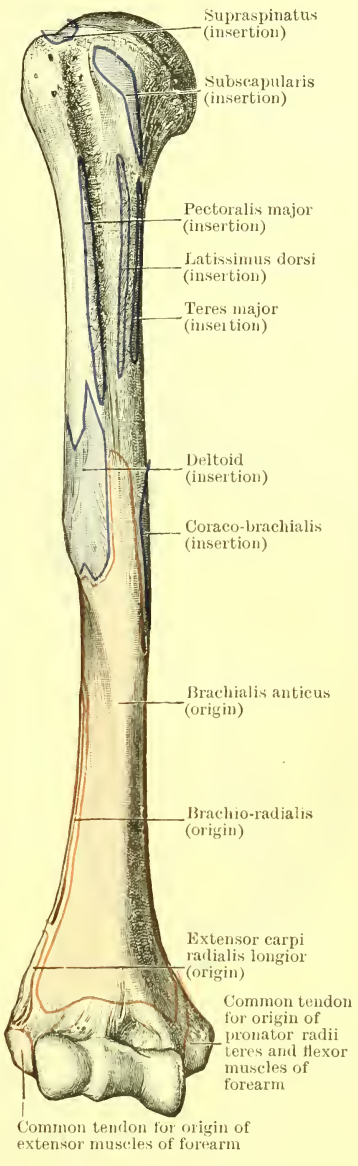


FIG. 253.—MUSCLE-ATTACHMENTS TO THE FRONT OF THE HUMERUS.

the dorsal scapular artery. The muscle is invested by the deep fascia enclosing the infraspinatus, and is sometimes inseparable from that muscle.

The **teres major** is much larger than the preceding muscle. It **arises** by fleshy fibres from the lower third of the flat surface on the dorsum of the scapula along its axillary border (except for a small area at the lower angle), and from fascial septa, which separate it on the one side from the subscapularis, and on the other from the infraspinatus and teres minor (Fig. 254, p. 330). The muscle is directed along the axillary border of the scapula to the front of the shaft of the humerus, where it is **inserted** by a broad flat tendon into the inner border of the bicipital groove internal to the latissimus dorsi muscle (Fig. 257, p. 335). Just before its insertion it is closely adherent to the tendon of the latissimus dorsi.

The teres major helps to form the posterior wall of the axilla. It lies below the subscapularis, and is in close relation with the latissimus dorsi muscle, which conceals its origin posteriorly, winds round its outer border, and partially separates its anterior surface from the axillary vessels and nerves. The muscle forms the lower boundary of a large triangular interval, bounded externally on the posterior wall of the axilla by the surgical neck of the humerus, and above by the borders of the subscapularis and teres minor muscles. The long head of the triceps passes behind the teres major and subdivides this space into two, a quadrilateral space limited by the triceps and surgical neck of the humerus for the passage of the circumflex nerve and posterior circumflex vessels, and a smaller triangular space bounded by the triceps, subscapularis, and teres major, for the dorsal scapular artery.

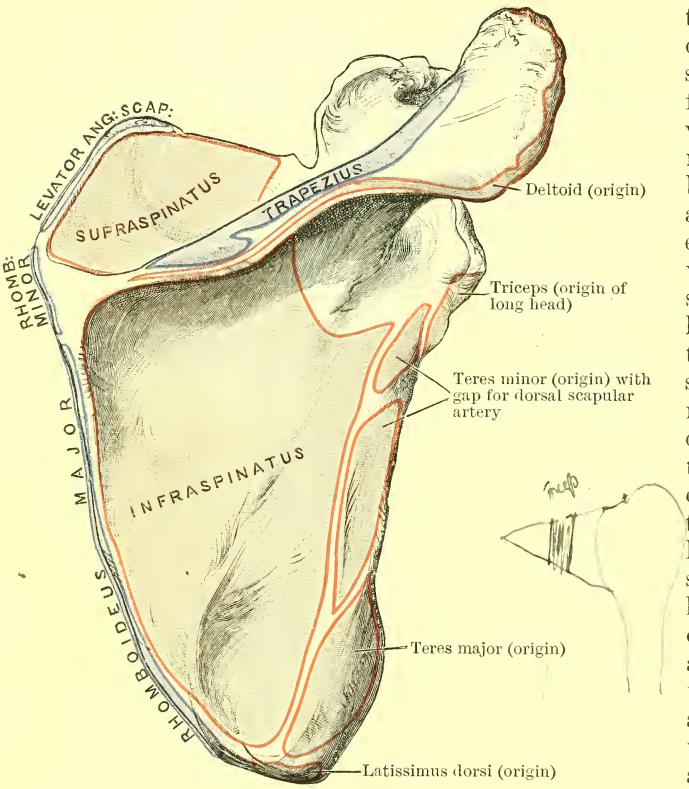


FIG. 254.—MUSCLE-ATTACHMENTS TO THE SCAPULA (Posterior Surface).

The **subscapularis** is a large triangular muscle occupying the venter of the scapula. It **arises** by fleshy fibres from the whole of the subscapular fossa and the groove along the axillary border, excepting the surfaces at the angles of the bone (Fig. 250, p. 325). Springing from several ridges in the fossa are septa projecting into the substance of the muscle, which increase the extent of its attachment. Converging to the head of the humerus, the muscular fibres are **inserted** by a broad, thick tendon into the lesser tuberosity of the humerus and into the capsule of the shoulder-joint, and by fleshy fibres into the surgical neck and the shaft of the humerus below the tuberosity for about an inch, under cover of the coraco-brachialis and short head of the biceps (Fig. 257, p. 335). This muscle forms the greater part of the posterior wall of the axilla. Its inner or anterior surface is in contact with the serratus magnus and the axillary vessels and nerves. Its deep surface is separated from the neck of the scapula by a bursa, which is in direct communication with the synovial cavity of the shoulder-joint. Its upper border passes beneath the coracoid process; its outer border is separated from the teres major by the posterior circum-

flex vessels and the circumflex nerve, the long head of the triceps muscle, and the dorsal scapular artery.

The **subscapularis minor** is an occasional muscle situated below the capsule of the shoulder-joint. It **arises** from the axillary border of the scapula below the subscapularis, and is **inserted** into the capsule of the joint or the upper part of the shaft of the humerus.

Nerve-Supply.

The muscles of this group are all supplied by the fifth and sixth cervical nerves, through nerves arising from posterior trunks of the brachial plexus.

Muscles.	Nerves.	Origin.
Deltoid, Teres minor	Circumflex	C. 5. 6.
Supraspinatus, Infraspinatus	Suprascapular	
Teres major	Lower subscapular	
Subscapularis	Lower and upper subscapular	

Actions.

The principal action of this group of muscles is on the shoulder-joint. They have also secondary actions in relation to movements of the trunk and limbs.

1. Movements at the Shoulder-Joint.

a. **Abduction.**	**Adduction.**	*b.* **Flexion** (Forwards).	**Extension** (Backwards).
Deltoid Supraspinatus	Teres major Teres minor Pectoralis major Latissimus dorsi Coraco-brachialis Biceps (short head) Triceps (long head) (Weight of limb)	Deltoid (anterior fibres) Subscapularis Pectoralis major Coraco-brachialis Biceps	Deltoid (posterior fibres) Teres major Infraspinatus Latissimus dorsi Triceps

c. **Rotation Outwards.**	**Rotation Inwards.**
Deltoid (posterior fibres) Infraspinatus Teres minor	Deltoid (anterior fibres) Teres major Pectoralis major Latissimus dorsi
d. **Circumduction**—combination of previous muscles.	

The various movements at the shoulder-joint are greatly aided by the muscles acting on the shoulder girdle. In raising the arm above the head, for instance, the humerus is brought to the horizontal position by the deltoid and supraspinatus, and the movement is continued by the elevators of the shoulder girdle. Again, in forward and backward movements at the shoulder-joint, great assistance is derived from muscles acting directly on the shoulder girdle—pectoralis minor and serratus magnus; trapezius and rhomboidei.

2. **In relation to the trunk and limbs,** the shoulder muscles, by fixing the humerus, have auxiliary power on the one hand in movements of the trunk, such as forced inspiration; on the other hand, acting along with muscles fixing the elbow-joint, they stiffen the limb so as to permit of the more refined movements of the wrist and fingers.

FASCIÆ AND MUSCLES OF THE ARM.

FASCIÆ.

The **superficial fascia** presents no features of importance. There is a bursa beneath it over the olecranon process, and occasionally another over the inner condyle of the humerus.

The **deep fascia** forms a strong tubular investment for the muscles on the front and back of the humerus. It is continuous above with the deep fascia of the shoulder and axilla, and is further strengthened by fibres derived from the insertions of muscles attached to the upper part of the humerus, viz., from the pectoralis major, latissimus dorsi, and deltoid. At the elbow it becomes continuous with the deep fascia of the forearm, and gains attachment to the condyles of the humerus and the olecranon process of the ulna; it is strengthened also by important bands associated with the insertions of the biceps in front and the triceps behind, to which reference will be made in the account of these muscles.

About the middle of the upper arm in front of the inner border, the deep fascia is perforated for the passage of the basilic vein and the internal cutaneous nerve.

The **intermuscular septa** are processes of the deep fascia attached to the supracondyloid or epicondylic ridges of the humerus. The **internal** and stronger **septum** is placed between the brachialis anticus in front and the inner head of the triceps behind, and gives origin to both. It extends upwards to the insertion of the coraco-brachialis (which is often continued into it), and the ulnar nerve and inferior profunda vessels pass down over its inner edge. The **external septum** is thinner. It separates the brachialis anticus and brachio-radialis in front from the inner and outer heads of the triceps behind, and gives origin to these muscles. It extends upwards to the insertion of the deltoid, and is pierced by the musculo-spiral nerve and superior profunda vessels.

MUSCLES.

The **coraco-brachialis** is a rudimentary muscle placed on the front and inner aspect of the arm. It **arises** in common with the short head of the biceps from the tip of the coracoid process of the scapula (Fig. 250, p. 325), and is commonly connected at its origin with the insertion of the pectoralis minor. The origin of the muscle is by fleshy fibres attached (1) to the tip of the coracoid process below and internal to the biceps tendon, and (2) to the tendon of the biceps itself. The muscle is partially subdivided into two parts by the musculo-cutaneous nerve, and ends in a flat tendon **inserted** into a faint linear impression about an inch in length on the middle of the inner border of the shaft of the humerus (Fig. 257, p. 335). It is often continued into the internal intermuscular septum.

The muscle lies on the inner side of the biceps, and is concealed at first by the deltoid and pectoralis major. In the lower part of its extent it is superficial, and forms a swelling beneath the skin on the inner side of the arm which serves as a guide to the axillary and brachial arteries.

The **coraco-brachialis** is the remains of a *threefold muscle*, of which only two elements are usually present in man, but of which in anomalous cases all the parts may be more or less fully developed. The passage of the musculo-cutaneous nerve through the muscle is an indication of its natural separation into two parts, which represent the persistent middle and inferior elements. The commonest variety is one in which the more superficial (inferior) part of the muscle extends farther down the arm than usual, so as to be inserted into the internal intermuscular septum, or even into the internal condyle of the humerus. A third slip (**coraco-brachialis superior** or **brevis, rotator humeri**) may more rarely be present, forming a short muscle **arising** from the root of the coracoid process, and **inserted** into the inner side of the humerus just below the capsule of the shoulder-joint.



The **biceps** (m. biceps brachii) is the large superficial muscle which lies on the front of the upper arm. It **arises** by two tendinous *heads*. (1) The **short head** (caput breve) is attached in common with the coraco-brachialis to the tip of the coracoid process of the scapula (Fig. 250, p. 325). Tendinous at first, this head forms a separate fleshy belly, which is united to the long head by an investment of the deep fascia.

(2) The **long head** (caput longum) arises by a round tendon from the supra-glenoid impression at the root of the coracoid process and from the glenoid ligament on either side. Its tendon traverses the cavity of the shoulder-joint, and emerging from the capsule beneath the transverse ligament (invested by a prolongation of the synovial membrane), it occupies the bicipital groove of the humerus, covered by a fascial prolongation of the tendon of the pectoralis major. In the upper arm it forms a fleshy belly united to that derived from the short head by an envelope of deep fascia.

The **insertion** of the muscle is likewise twofold. (1) The two bellies become connected with a strong *tendon*, attached deeply in the hollow of the elbow to the rough posterior portion of the bicipital tubercle of the radius (Figs. 264, p. 343, and 271, p. 351). A bursa separates the tendon from the anterior portion of the tubercle. (2) From the inner and anterior part of the tendon, and partly in continuity with the fleshy fibres of the muscle, a strong *membranous band* (the **semilunar** or **bicipital fascia**) extends downwards and inwards over the hollow of the elbow to join the deep fascia covering the origins of the flexor and pronator muscles of the forearm. Its upper part is thickened and can be felt subcutaneously as a crescentic border.

Except at its origin and insertion the biceps muscle is placed superficially on the front of the arm, concealing the brachialis anticus muscle and the musculo-cutaneous nerve. The brachial artery and median nerve lie along its inner border. The origin of the muscle is deeply placed under cover of the deltoid and pectoralis major. The tendon of insertion in the hollow of the elbow lies beneath the end of the brachial and the beginning of the radial artery. The bicipital fascia separates the brachial artery from the median basilic vein.

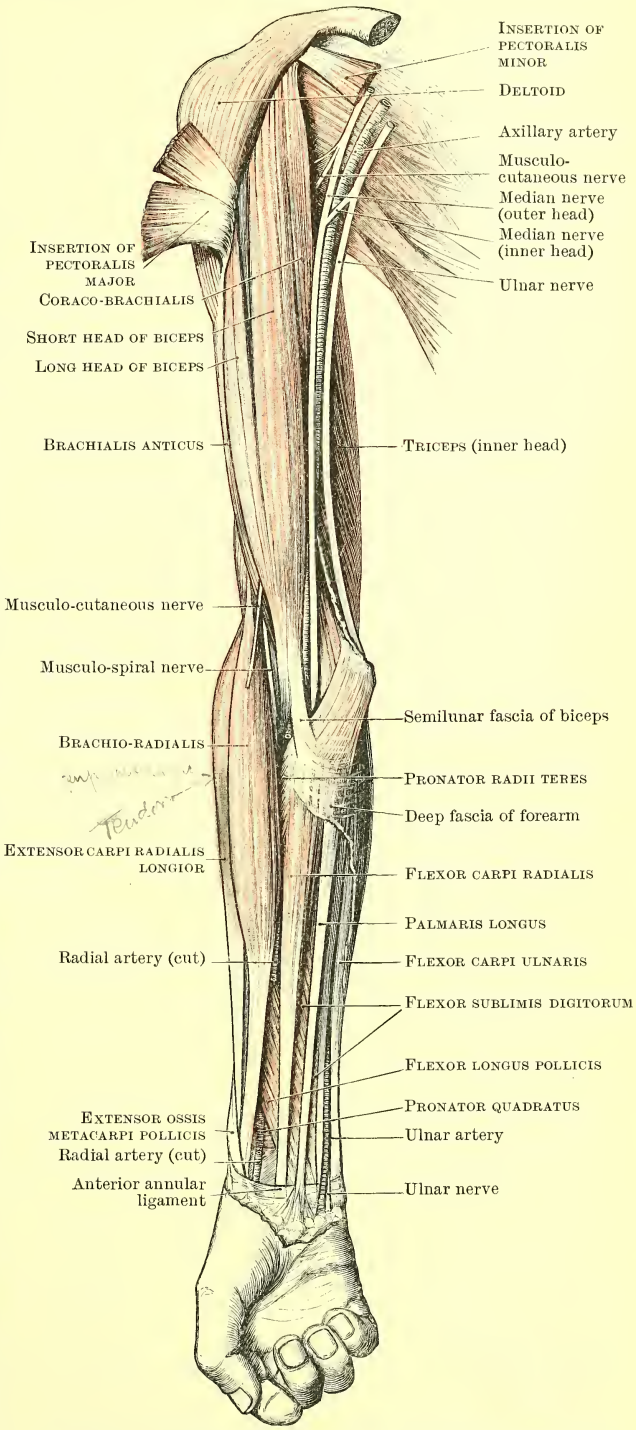


Fig. 255.—Superficial Muscles on the Front of the Arm and Forearm.

The **biceps** is an extremely variable muscle. Its chief anomalies are due to an increase or diminution in the number of origins. A third **head of origin** is common (10 per cent), and usually arises from the humerus, between the insertions of the deltoid and coraco-brachialis. Two or even three additional heads may be present at the same time. The long head of the muscle may be absent, or may take origin from the bicipital groove. The muscle may have an additional insertion into the internal condyle of the humerus, or into the fascia of the forearm.

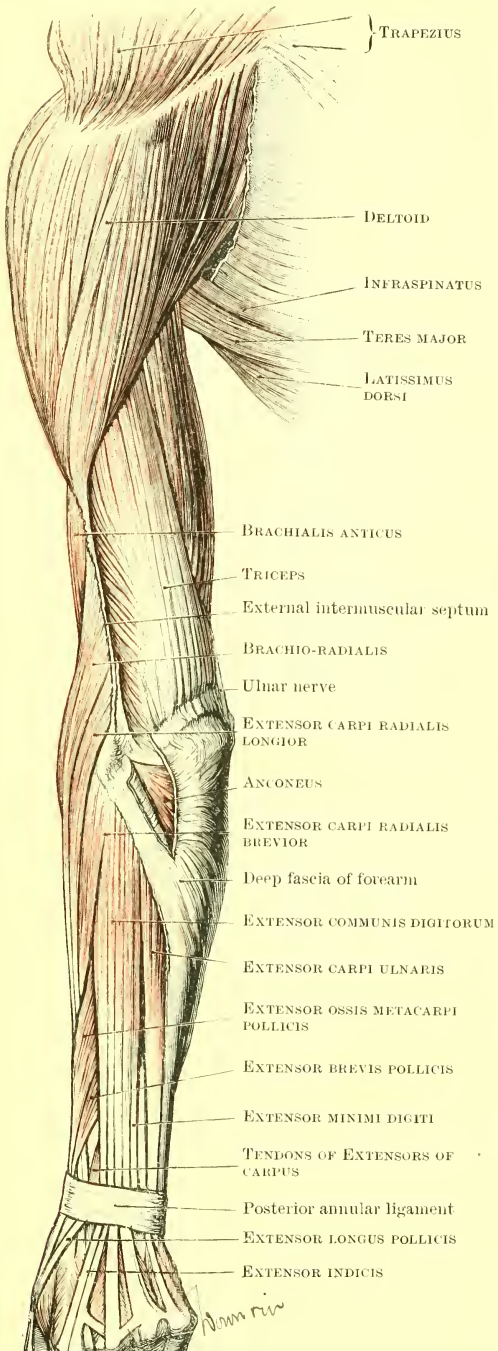


Fig. 256.—The Muscles on the Back of the Arm, Forearm, and Hand.

The **brachialis anticus** (m. brachialis) is a large muscle **arising** from the lower two-thirds of the front of the shaft of the humerus, and from the inter-muscular septum on each side (Figs. 257 and 258, p. 335). Clasping the insertion of the deltoid above, it ends below in a strong tendon **inserted** into the rough inferior surface of the coronoid process of the ulna and into the anterior surface of the shaft of the bone immediately below (Fig. 264, p. 343). A few of the deep fibres are inserted into the anterior ligament of the elbow-joint. The outer part of the muscle arising from the external epicondylic ridge and external intermuscular septum forms a slip more or less separate, which may be partially fused with the brachio-radialis muscle.

The brachialis anticus is almost wholly concealed from view by the biceps in front, the brachio-radialis externally, and the brachial vessels internally. It covers the elbow-joint, and forms part of the floor of the hollow of the elbow. It is separated from the brachio-radialis and extensor muscles of the carpus by the musculo-spiral nerve.

The **triceps** (m. triceps brachii) is the only muscle on the back of the arm. It **arises** by three heads: an outer and an inner head, from the humerus, and a middle or long head from the scapula. (1) The **middle, long** or **scapular head** (caput longum) begins as a strong tendon attached to a rough triangular surface on the axillary border of the scapula just below the glenoid fossa (Figs. 254, p. 330, and 250, p. 325). This gives rise to a fleshy belly which occupies the middle of the back of the arm. (2) The **outer head** (caput laterale) is attached by fibres, partly tendinous and partly fleshy, to the curved outer border of the humerus from the insertion of the teres minor above to the musculo-spiral groove below, and receives additional fibres from the back of the external intermuscular septum (Fig. 258, p. 335). This origin is thick above and becomes

linear below. Its fibres are directed downwards and inwards over the musculo-spiral groove and the inner head of the muscle to the tendon of insertion (3) The **inner head** (caput mediale) arises by fleshy fibres from an elongated triangular area on the back of the humerus, extending upwards to the level of the insertion of the teres major on the inner side, and downwards nearly to the margin of the olecranon fossa. (Fig. 258, p. 335). Externally it is limited above by the musculo-spiral groove;

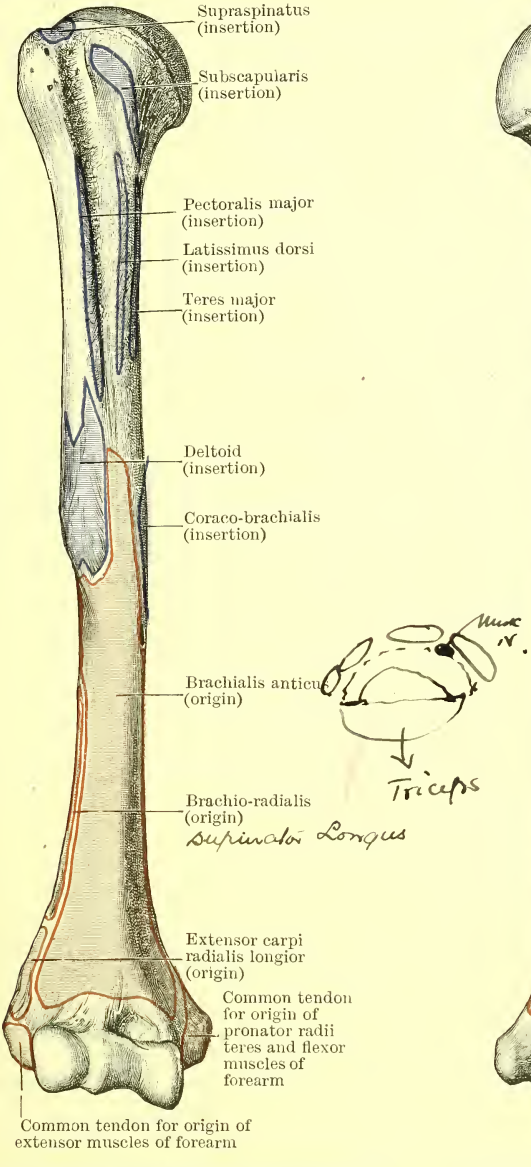


FIG. 257.—MUSCLE-ATTACHMENTS TO THE FRONT OF THE HUMERUS.

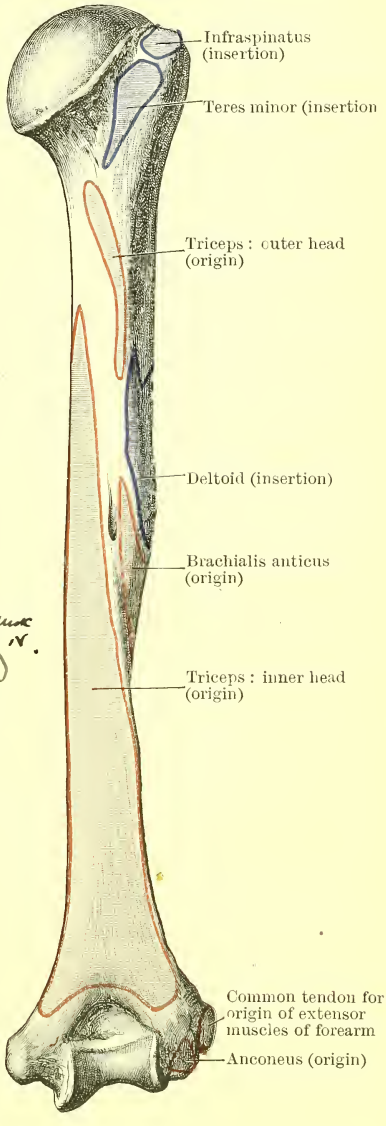


FIG. 258.—MUSCLE-ATTACHMENTS TO THE BACK OF THE HUMERUS.

and below it extends downwards on either side of the olecranon fossa almost to the condyles of the humerus. It also arises on each side from the intermuscular septa,—from the whole length of the internal septum, and from the part of the external septum which is below the passage of the musculo-spiral nerve.

The three heads of origin are **inserted** by a common tendon, broad and membranous, into an impression occupying the posterior part of the upper end of the olecranon process of the ulna (Fig. 271, p. 351), and into the deep fascia of the forearm on either side of it. The long and outer heads join the borders of the tendon of

insertion, and the inner head is attached to its deep surface. A small thick-walled bursa separates the tendon of the triceps from the posterior ligament of the elbow-joint and the anterior part of the upper end of the olecranon process.

The long head of the triceps is concealed at first by the teres major and teres minor, and by the deltoid muscle. Along with the outer head it conceals the musculo-spiral nerve and superior profunda artery, and covers the inner head of the muscle. The inner is the deep head, and is only visible at the lateral borders of the muscle.

The **subanconeus** is a small muscle occasionally present, which consists of scattered fibres **arising** from the lower end of the humerus beneath the triceps, and **inserted** into the posterior ligament of the elbow-joint.

Nerve-Supply.

The following nerves supply the muscles of the arm :—

Muscles.	Nerves.	Origin.
Coraco-brachialis Biceps Brachialis anticus	Musculo-cutaneous	C. 7. C. 5. 6. C. 5. 6.
Brachialis anticus Triceps Outer head Middle and inner heads	Musculo-spiral	C. (5) 6. C. (6) 7. 8. C. 7. 8.

Actions.

(1) The chief action of these muscles (excepting the coraco-brachialis) is on the elbow-joint, producing along with other muscles flexion and extension. The flexor muscles are much more powerful than the extensors.

Table of Muscles acting on the Elbow-Joint.

Flexors.	Extensors.
Biceps	Triceps
Brachialis anticus	Anconeus
Brachio-radialis	Extensors of wrist and fingers (in supination)
Pronator radii teres	
Flexors of wrist and fingers	
Extensors of wrist (in pronation)	

(2) **The coraco-brachialis** muscle acts only on the shoulder-joint, assisting the biceps as an adductor and flexor of the humerus.

(3) **Subordinate** and **accessory movements** are performed by all the muscles of this group except the brachialis anticus. The **biceps** supinates the forearm, flexes the elbow, and with the aid of the **coraco-brachialis** adducts and flexes the humerus at the shoulder-joint. The **triceps** through its scapular head adducts and extends the humerus, besides extending the elbow-joint.

FASCIÆ AND MUSCLES OF THE FOREARM AND HAND.

FASCIÆ.

The **superficial fascia** in the forearm presents no exceptional features. On the dorsum of the hand it is loose and thin; in the palm it is generally well furnished with fat, forming pads for the protection of the vessels and nerves. It is closely adherent to the palmar fascia and to the skin, especially along the lines of flexure.

The **palmaris brevis** is a quadrilateral subcutaneous muscle occupying the inner side of the hand under the superficial fascia. It **arises** from the inner border of the thick central portion of the palmar fascia and from the front of the anterior annular ligament of the wrist, and is **inserted** into the skin of the inner border of the hand for a variable distance. It covers the ulnar artery and nerve, branches of which supply it. Its action is to wrinkle the skin of the inner border of the

hand, and by raising up the skin and superficial fascia, to deepen the hollow of the hand.

The **deep fascia** of the forearm and hand is continuous above with the deep fascia of the arm. At the upper part of the forearm it is strengthened by additional fibres around the elbow; in front by fibres from the semilunar fascia of the biceps, behind by the fascial insertions of the triceps, and laterally by fibres derived from the humeral condyles in relation to the common tendons of origin of the flexor and extensor muscles of the forearm. It closely invests and gives origin to these muscles. It is attached to the posterior border of the ulna in the whole length of the forearm, and affords increased attachment to the flexor and extensor carpi ulnaris and the flexor profundus digitorum muscles. Above the wrist the fascia is pierced anteriorly by the tendon of the palmaris longus, and by the ulnar artery and nerve. At the wrist it gains attachment to the bones of the forearm and carpus, is greatly strengthened by addition of transverse fibres, and constitutes **the annular ligaments.**

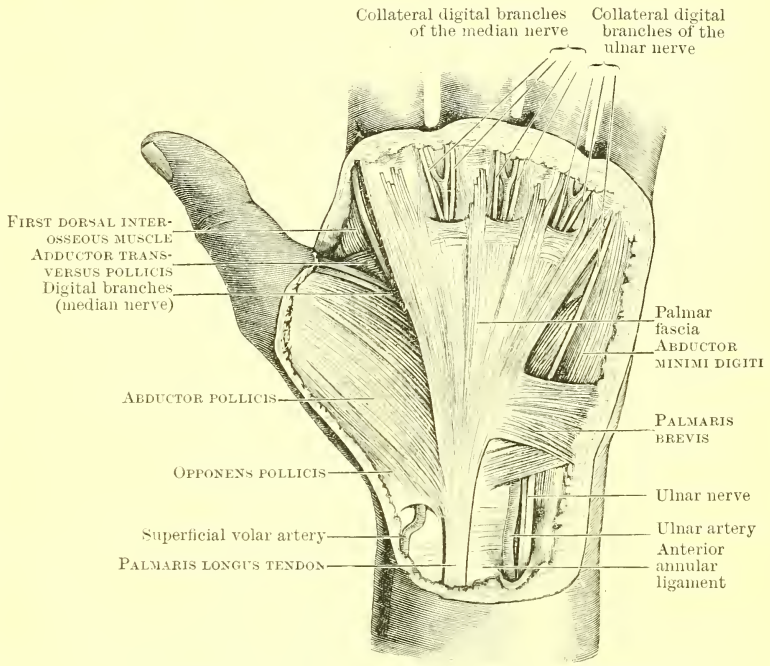


Fig. 259.—The Palm of the Hand (Superficial Dissection).

The **anterior annular ligament** of the wrist is a band about an inch and a half in depth, continuous above and below with the deep fascia of the forearm and the palm of the hand. It is attached to the scaphoid and trapezium externally: to the pisiform and unciform bones internally; and it forms a membranous arch binding down in the hollow of the carpus the flexor tendons of the fingers and the median nerve. It is divided into *two compartments*, the larger accommodating the tendons of the flexors of the digits and the median nerve, the smaller (placed externally) containing the tendon of the flexor carpi radialis. There are *three synovial membranes* in these compartments: one for the flexor carpi radialis tendon, and two others, which often communicate together, enveloping the tendon of the flexor longus pollicis and the flexor tendons of the fingers respectively. The surface of the ligament is crossed by the palmar branches of the median and ulnar nerves; by the tendon of the palmaris longus muscle, which is attached to its surface; and by the ulnar artery and nerve, which are again bridged over and protected by a band of fibrous tissue passing from the pisiform bone and the superficial fascia to the surface of the ligament. To the lower border of the ligament are attached the palmar fascia in the centre, and the superficial muscles of the thumb and the muscles of the little finger on each side.

The **posterior annular ligament** of the wrist is placed at a higher level than the previous ligament. It consists of an oblique band of fibres about an inch broad, continuous above and below with the deep fascia of the forearm and hand. It is attached externally to the outer side of the lower end of the radius, and internally to the lower end of the ulna (styloid process), the carpus, and the internal lateral ligament of the wrist. It is covered by veins, by the radial nerve,

and by the dorsal branch of the ulnar nerve. *Six compartments* are formed beneath it by the attachment of septal bands to the lower ends of the radius and ulna. Each compartment is provided with a *synovial membrane*, and they serve to transmit the extensor tendons of the wrist and fingers in the following order from without inwards:—

1. Extensor ossis metacarpi pollicis and extensor brevis pollicis.
2. Extensores carpi radiales, longior and brevior.
3. Extensor longus pollicis.
4. Extensor communis digitorum and extensor indicis.
5. Extensor minimi digiti.
6. Extensor carpi ulnaris.

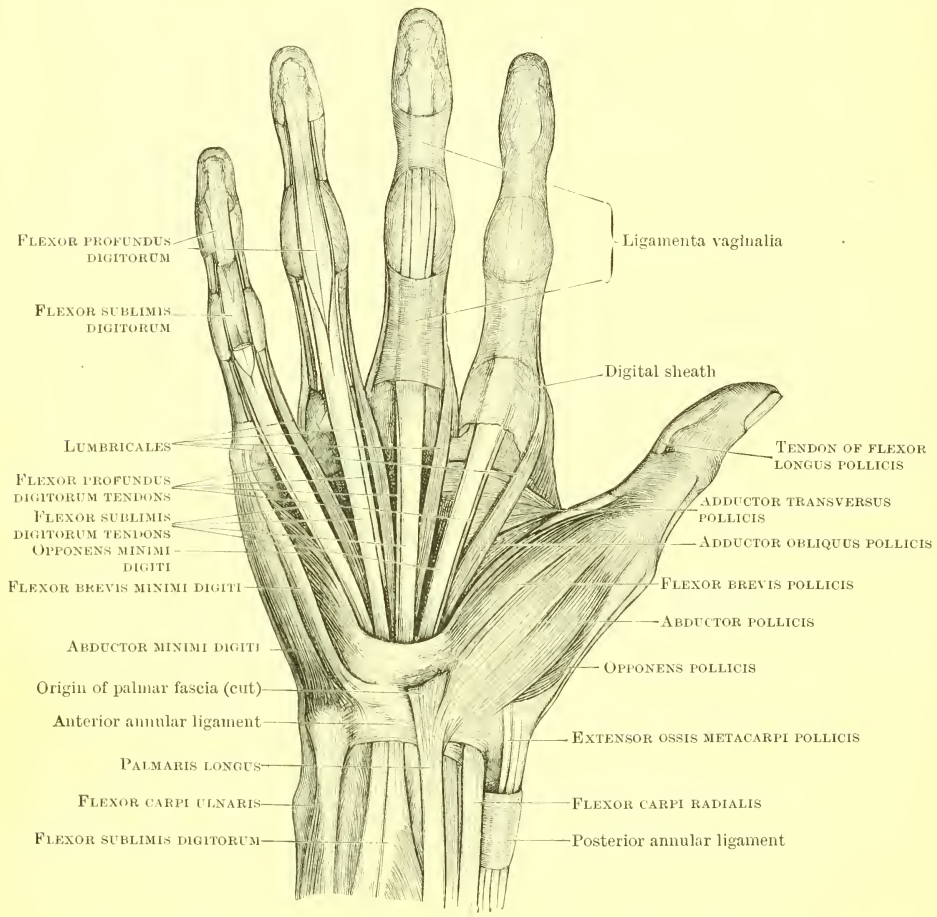


Fig. 260.—The Muscles and Tendons in the Palm of the Hand.

The thin deep fascia of the dorsum of the hand is lost over the expansions of the extensor tendons on the fingers. Between the metacarpal bones a strong layer of fascia covers and gives attachment to the interossei muscles.

The **palmar fascia** is of considerable importance. In the centre of the palm it forms a thick triangular membrane, the apex of which joins the lower edge of the anterior annular ligament, and receives the insertion of the tendon of the palmaris longus muscle. The fascia separates below into four slips, one for each finger, connected together by transverse fibres, forming beneath the webs of the fingers the **superficial transverse metacarpal ligament**. Beyond this each slip separates into two parts, to be connected to the sides of the metacarpo-phalangeal joints and the first phalanx of the inner four digits. In the cleft between the two halves of each slip the **digital sheath** is attached and extends downwards on to the finger. The lateral borders of this triangular central portion of the palmar fascia

are continuous with thin layers of deep fascia, which cover and envelop the muscles of the thenar and hypothenar eminences. The inner border gives origin to the *palmaris brevis muscle.*

The **digital sheaths** are tubular envelopes extending along the anterior aspect of the digits and enclosing the flexor tendons. Each consists of a fibrous sheath attached to the lateral borders of the phalanges and inter-phalangeal joints, and continuous above with the palmar fascia. Opposite each inter-phalangeal articulation the digital sheath is loose and thin; opposite the first two phalanges (the first only in the case of the thumb) it becomes extremely thick, and gives rise to the **ligamenta vaginalia**, which serve to keep the tendons closely applied to the bones during flexion of the fingers. Within each digital sheath are the flexor tendons, enveloped in a synovial membrane which not only envelops the tendon, but also lines the interior of the sheath. The synovial membranes of the digital sheaths extend a short distance upwards in the palm, and in some cases communicate with the large synovial membranes lining the flexor tendons beneath the annular ligament. There may be a separate distinct synovial membrane for each digit; but most commonly only the sheaths for the three middle digits have separate synovial membranes; those for the flexor longus pollicis and for the flexor tendons of the little finger communicate usually with the synovial membranes placed beneath the anterior annular ligament.

THE MUSCLES ON THE FRONT AND INNER ASPECT OF THE FOREARM.

The pronator and flexor muscles which lie on the front of the forearm occupy different levels, and are divisible into two main groups, **superficial** and **deep**.

Superficial Muscles.

The **superficial muscles** form the prominence on the front and inner side of the forearm, and all take origin in whole or part by means of a common tendon from the internal condyle of the humerus. The group comprises five muscles—pronator radii teres, flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and flexor sublimis digitorum.

The **pronator radii teres** (m. pronator teres) is the most external and shortest muscle of this group. It has a double **origin**: (1) a *superficial head*, the main origin, partly fleshy, partly tendinous, from the lowest part of the internal supracondyloid ridge of the humerus and from the internal intermuscular septum, from the internal condyle of the humerus, from the fascia over it, and from an intermuscular septum between it and the flexor carpi radialis (Fig. 257, p. 335); (2) a *deep head*, a slender tendinous slip from the inner side of the coronoid process of the ulna, which joins the superficial origin of the muscle on its deep surface (Fig. 264, p. 343). The median nerve separates the two heads from one another. The muscle is directed downwards and outwards to be **inserted** by tendon into an oval impression on the middle of the outer surface of the shaft of the radius (Figs. 264, p. 343, and 271, p. 351). The fibres of the muscle are twisted on themselves, so that the highest humeral fibres form the lowest fibres of the tendon of insertion, and the lowest humeral fibres and those arising from the coronoid process are highest at the insertion of the muscle.

The muscle forms the inner boundary of the hollow of the elbow. It is superficially placed, except near its insertion, where it is covered by the brachio-radialis muscle and by the radial vessels and nerve. The flexor carpi radialis is on its inner side. The muscle conceals the ulnar and radial origins of the flexor sublimis digitorum, and the median nerve and ulnar artery, which are separated from one another by the deep head of origin.

The **flexor carpi radialis** muscle takes its **origin** from the common tendon from the internal condyle of the humerus, from the fascia over it, and from the intermuscular septa on either side. Its fleshy belly gives place to a strong round tendon in the lower half of the forearm, which, at the wrist, enters the hand in a

special compartment beneath the anterior annular ligament, and after occupying the groove on the trapezium, is **inserted** into the upper ends of the second and third metacarpal bones on their anterior surfaces. The chief tendon is that to the second metacarpal bone, which gives off a small slip on its inner side to be attached to the third metacarpal bone. Each is inserted about a quarter of an inch below the carpo-metacarpal joint (Fig. 267, p. 346).

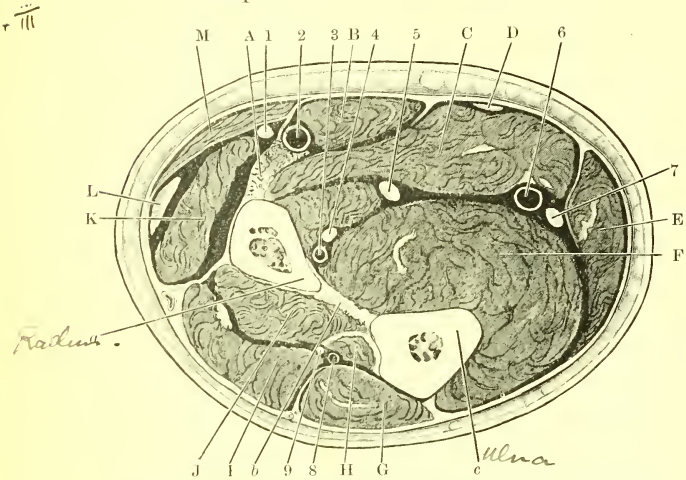


Fig. 261.—Section across the Forearm in the Middle Third.

A, Pronator radii teres (insertion); B, Flexor carpi radialis; C, Flexor sublimis digitorum; D, Palmaris longus; E, Flexor carpi ulnaris; F, Flexor profundus digitorum; G, Extensor carpi ulnaris; H, Extensor longus pollicis; I, Extensor communis digitorum and extensor minimi digiti; J, Extensor ossis metacarpi pollicis; K, Extensor carpi radialis brevior; L, Extensor carpi radialis longior; M, Brachio-radialis. *a*, Radius; *b*, Interosseous membrane; *c*, Ulna. 1, Radial nerve; 2, Radial Artery; 3, Anterior interosseous artery; 4, Anterior interosseous nerve (underneath flexor longus pollicis); 5, Median nerve; 6, Ulnar artery 7, Ulnar nerve; 8, Posterior interosseous artery; 9, Posterior interosseous nerve.

The flexor carpi radialis is superficial except near its insertion. Its fleshy belly in the upper half of the forearm lies between the pronator radii teres and the palmaris longus, and conceals the flexor sublimis digitorum. Its tendon in the lower half of the forearm is subcutaneous, on the outer side of the palmaris longus tendon. It is an important guide to the radial vessels which are placed in the hollow external to it. Just above the wrist it crosses obliquely the tendon of the flexor longus pollicis. After passing beneath the anterior annular ligament the tendon is concealed by the origins of the short muscles of the thumb, and is crossed from within outwards by the tendon of the flexor longus pollicis. Besides the synovial bursa enveloping the tendon beneath the annular ligament, another is found beneath the tendons at their insertion.

The **palmaris longus** arises also from the common flexor tendon, from the internal condyle of the humerus, from the fascia over it, and from intermuscular septa on either side. It forms a short fusiform muscle, which ends in the middle of the forearm in a long flat tendon. This pierces the deep fascia above the wrist, and passing over the anterior annular ligament, is **inserted** (1) into the surface of the anterior annular ligament, and (2) into the apex of the thick central portion of the palmar fascia. A tendinous slip is frequently sent to the short muscles of the thumb and the fascia covering them.

The palmaris longus is the smallest muscle of the forearm. It is placed between the flexor carpi radialis and the flexor carpi ulnaris, and upon the flexor sublimis digitorum. In the lower third of the forearm its tendon is placed directly over the median nerve, along the outer border of the tendons of the flexor sublimis digitorum.

The palmaris longus is the most variable muscle in the body, and is often absent (10 per cent).

The **flexor carpi ulnaris** muscle has a double **origin**, from the humerus and from the ulna. (1) It arises from the common tendon attached to the inner condyle of the humerus, from the fascia over it, and from an intermuscular septum externally. (2) By means of the deep fascia of the forearm it obtains an attachment to the inner border of the olecranon process and the posterior border of the ulna in its upper three-fifths. The fleshy fibres join a tendon which lies on the anterior border of the muscle and is **inserted** into the pisiform bone. From the pisiform bone the fibres are continued in the form of two ligamentous bands (pisi-unciform and pisi-metacarpal) to be attached to the upper margin of the hook of the unciform bone, and the palmar surface of the upper end of the fifth metacarpal bone (Fig. 267, p. 346).

The muscle is superficially placed along the inner border of the forearm. It lies internal to the palmaris longus and flexor sublimis digitorum, and conceals the flexor profundus digitorum muscle. The ulnar nerve (which enters the forearm between the two heads of origin of the muscle) is concealed by it in its whole length. The ulnar artery lies undercover of the muscle in its lower two-thirds. The tendon of the muscle serves as a guide to the artery in the lower half of the forearm.

The **flexor sublimis digitorum** occupies a deeper plane than the four previous muscles. It has a threefold **origin**, from the humerus, radius, and ulna. (1) The chief or *humeral* origin is from the internal condyle of the humerus by the common tendon, from the internal lateral ligament of the elbow, and from adjacent inter-muscular septa. (2) The *ulnar* origin is by a slender fasciculus from the inner border of the coronoid process of the ulna, above and internal to the origin of the pronator radii teres (Fig. 264, p. 343). (3) The *radial* origin is from the oblique line and middle third of the anterior border of the radius by a thin fibro-muscular attachment (Fig. 264, p. 343).

The muscle divides in the lower third of the forearm into four parts, each provided with a separate tendon which passes beneath the anterior annular ligament, traverses the palm of the hand, and enters the corresponding digital sheath. Within the digital sheath each tendon is split into two parts by the tendon of the flexor profundus digitorum; after surrounding that tendon the two parts are partially re-united on its deep surface, and are **inserted**, after partial decussation, in two portions into the sides of the second phalanx.

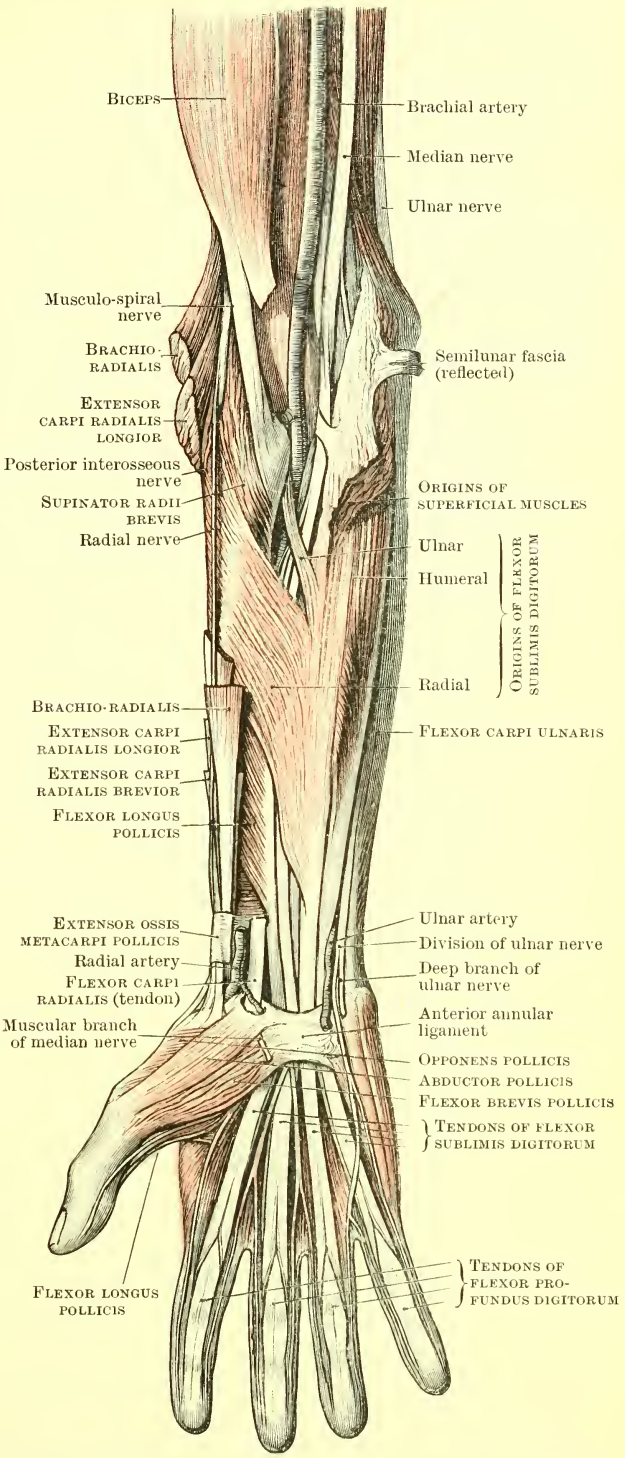


Fig. 262.—The Muscles and Nerves on the Front of the Forearm and Hand.

The pronator radii teres, flexor carpi radialis, and palmaris longus have been removed.

The **vincula accessoria tendinum** form additional insertions of the muscle. They consist of delicate bands of connective tissue enveloped in synovial membrane, and are known as the **ligamenta longa** and **brevia**. The ligamentum breve is a triangular band of fibres containing yellow elastic tissue (ligamentum subflavum), occupying the interval between the tendon and the digit for a short distance close to the insertion. It is attached to the front of the inter-phalangeal articulation and the head of the first phalanx. The ligamentum longum is a long narrow band extending from the back of the tendon to the upper part of the anterior surface of the first phalanx.

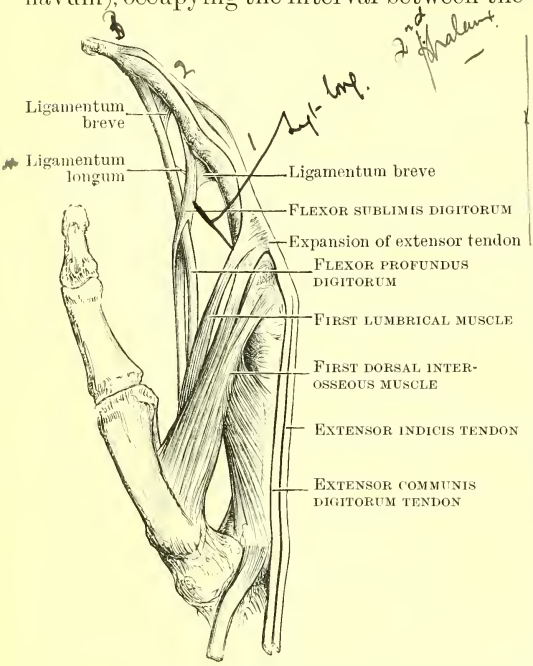


Fig. 263.—The Tendons attached to the Index Finger.

The flexor sublimis digitorum muscle is partially concealed in the forearm by the pronator radii teres, flexor carpi radialis, and palmaris longus muscles, and by the radial vessels and nerve. It conceals the flexor profundus digitorum and flexor longus pollicis muscles, the median nerve, and the ulnar artery. Its inner border is in contact with the flexor carpi ulnaris, and in the lower half of the forearm with the ulnar vessels and nerve. The median nerve emerges at its outer border above the wrist, and separates the muscle from the tendon of the flexor carpi radialis. At the wrist the four tendons are arranged in pairs, those for the middle and ring fingers in front, those for the fore and little fingers behind, and are enveloped in a synovial sheath (along with the tendons of the flexor profundus digitorum) beneath the anterior annular ligament. In the palm the tendons separate, and lying beneath the superficial palmar arch conceal the tendons of the deep flexor and the lumbrical muscles. Within the digital sheaths on the fingers the tendons at first conceal those of the deep flexor; after being pierced by them, they are in turn concealed by these tendons at their insertion.

Deep Muscles.

The **deep muscles** on the front of the forearm are three in number: flexor profundus digitorum, flexor longus pollicis, and pronator quadratus.

The **flexor profundus digitorum** is a large muscle **arising** from the ulna, the interosseous membrane, and the deep fascia of the forearm. Its ulnar origin is from the anterior and inner surfaces of the bone in its upper two-thirds, extending up so as to include the inner side of the olecranon process, and to embrace the insertion of the brachialis anticus into the coronoid process. It arises externally from the inner half of the interosseous membrane in its middle third (Figs. 264, p. 343, and 271, p. 351), and internally from the deep fascia of the forearm behind the origin of the flexor carpi ulnaris.

The muscle forms a broad thick tendon which passes beneath the anterior annular ligament, and divides in the palm into four tendons for **insertion** into the terminal phalanges of the fingers. The tendon associated with the forefinger is usually separate from the rest of the tendons in its whole length. Each tendon enters a digital sheath beneath the tendon of the flexor sublimis digitorum, which it pierces opposite the first phalanx, and is finally inserted into the base of the terminal phalanx. Like the tendons of the flexor sublimis, those of the deep

flexor are provided with vincula accessoria, viz. **ligamenta brevia** attached to the capsule of the second inter-phalangeal articulation, and **ligamenta longa**, which are in this case connected to the tendons of the subjacent flexor sublimis digitorum.

Lumbricales.—Four small cylindrical muscles are associated with the tendons of the flexor profundus digitorum in the palm of the hand. *The two outermost muscles* **arise** each by a single head from the radial sides of the tendons of the flexor profundus digitorum destined respectively for the fore and middle fingers. *The two innermost muscles* **arise**, each by two heads, from the adjacent sides of the second and third, and third and fourth tendons. From these origins the muscles are directed downwards to the radial side of each of the metacarpo-phalangeal joints, to be **inserted** into the capsules of these articulations, the outer border of the first phalanx, and chiefly into the outer side of the extensor tendon on the dorsum of the phalanx. The lumbricales vary considerably in number, and may be increased to six or diminished to two.

In the forearm the flexor profundus digitorum is concealed by the flexor sublimis digitorum and flexor carpi ulnaris muscles, and by the ulnar nerve and artery. Under the anterior annular ligament the muscle is placed beneath the tendons of the flexor sublimis digitorum, and is enveloped in the common bursal sac. In the palm the tendons, along with the lumbrical muscles, cover the deep palmar arch and the interossei muscles, and are concealed by the tendons of the flexor sublimis digitorum. On the finger each tendon is placed at first beneath, and afterwards pierces, the tendon of the flexor sublimis digitorum in its passage through the digital sheath. The lumbrical muscles passing downwards on the radial side of the deep flexor tendons lie beneath the digital vessels and nerves on their way to their insertion.

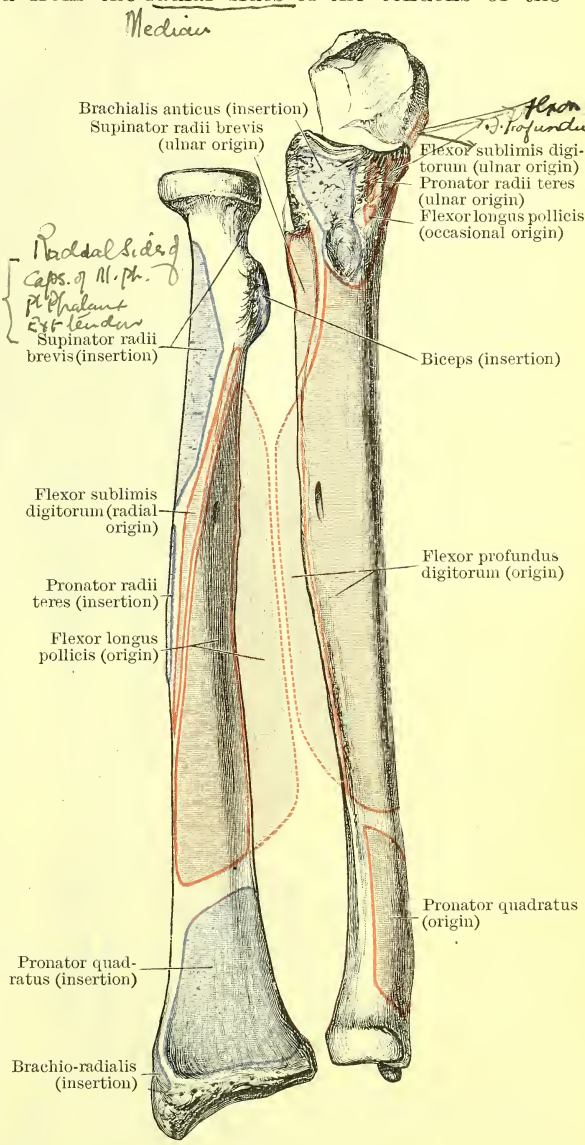


FIG. 264.—MUSCLE-ATTACHMENTS TO THE RADIUS AND ULNA (Anterior Aspects).

The **flexor longus pollicis arises** by fleshy fibres from the anterior surface of the shaft of the radius in its middle two-fourths, and from a corresponding portion of the interosseous membrane. It has an additional origin occasionally from the inner border of the coronoid process of the ulna (Fig. 264, p. 343). Its radial origin is limited above by the oblique line and the origin of the flexor sublimis digitorum, and below by the insertion of the pronator quadratus muscle. The muscle ends above the wrist in a tendon, which passes into the hand beneath the anterior annular ligament, enveloped in a special synovial sheath. In front of the carpus it crosses over the tendon of the flexor carpi radialis. In the palm the

tendon is directed downwards along the inner side of the thenar eminence, between the flexor brevis and adductor muscles of the thumb, to be **inserted** into the base of the terminal phalanx of the thumb on its anterior surface.

In the forearm the muscle is deeply placed beneath the flexor sublimis digitorum and flexor carpi radialis muscles. The radial artery lies upon it, and the anterior interosseous artery and nerve intervene between it and the flexor profundus digitorum. It crosses over the insertion of the pronator quadratus near the wrist.

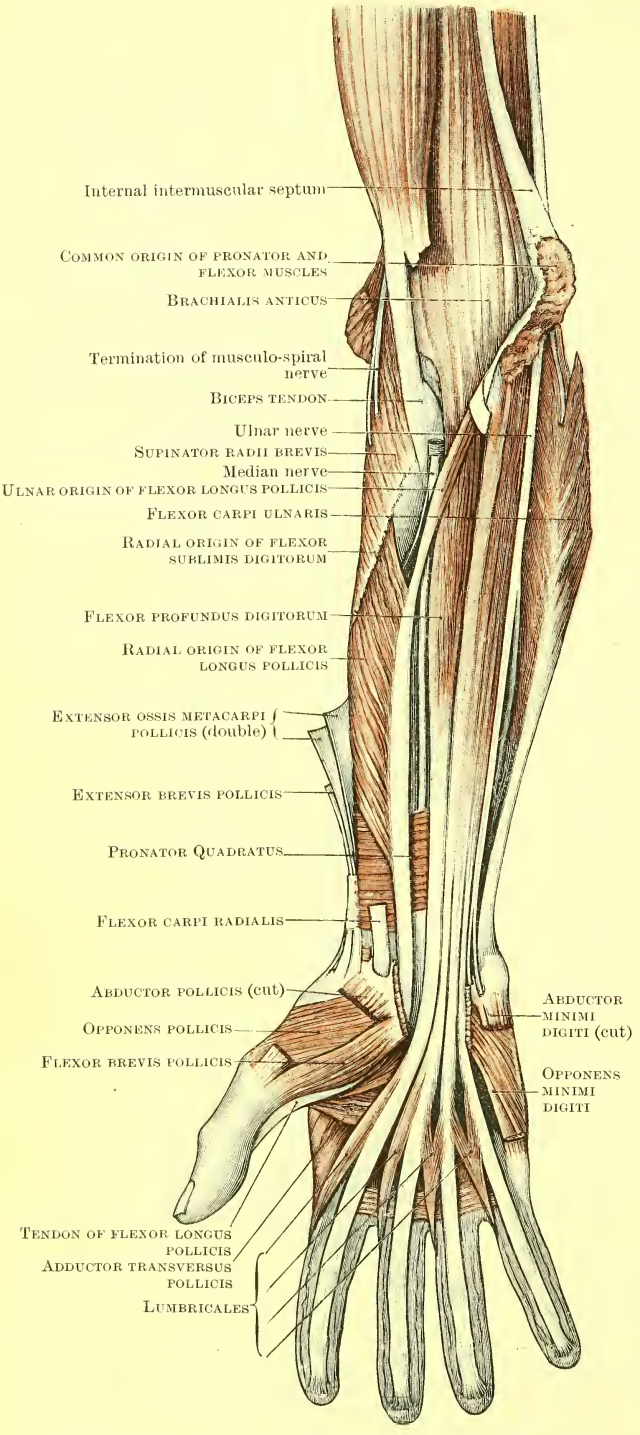


Fig. 265.—Deep Muscles on the Front of the Forearm and Hand.

The **pronator quadratus** is a quadrilateral fleshy muscle, occupying the lower fourth of the forearm. It **arises** from the lower fourth of the anterior border and surface of the ulna and frequently from the adjoining part of the inner surface (Fig. 271, p. 351), and is directed transversely outwards to be **inserted** into the lower fourth of the anterior surface of the radius, and into the narrow triangular area on its inner side in front of the attachment of the interosseous membrane (Fig. 264, page 343).

The muscle is deeply placed beneath the flexor tendons, the radial and ulnar arteries, and the ulnar and median nerves. It conceals the lower part of the interosseous membrane, the radius and ulna, and the anterior interosseous artery and nerve, which pass behind its upper border. The pronator quadratus is subject to considerable variations. It may even be absent; or it may have an origin from radius or ulna, or from both bones, and an insertion into the carpus.

SHORT MUSCLES OF THE HAND.

Muscles of the Thumb.

The short muscles of the thumb are six in number, abductor, opponens, and flexor brevis (with its deep portion, **interosseus primus volaris**), and two adductor muscles, adductor obliquus, and adductor transversus pollicis.

The **abductor pollicis** (m. abductor pollicis brevis) **arises** by fleshy fibres from the tubercle of the scaphoid, the upper part of the outer surface of the ridge of the trapezium, the upper part of the anterior surface of the anterior annular ligament at its outer end, and from tendinous slips derived from the insertions of the palmaris

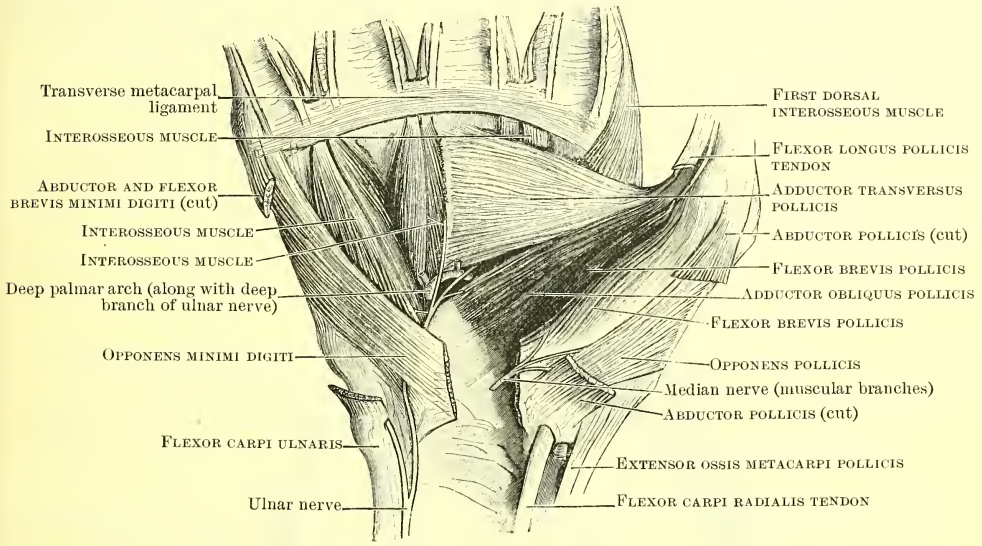


Fig. 266.—Short Muscles of the Hand.

longus and extensor ossis metacarpi pollicis muscles (Fig. 267, p. 346). Strap-like in form, it is **inserted** by a short tendon into the outer side of the first phalanx of the thumb at its upper end, and into the capsule of the metacarpo-phalangeal joint.

It is the most superficial muscle of the thenar eminence, and conceals partially the opponens and the superficial portion of the flexor brevis pollicis.

The **opponens pollicis arises** beneath the preceding muscle by fleshy and tendinous fibres from the lower and outer part of the anterior surface of the anterior annular ligament and from the outer surface of the ridge on the trapezium. Extending downwards and outwards, it is **inserted** into the whole length of the outer border and the radial half of the palmar surface of the first metacarpal bone (Fig. 267, p. 346). The muscle is superficial along the outer border of the abductor pollicis.

The **flexor brevis pollicis** consists of two parts. *a. The superficial part of the muscle* **arises** by fleshy and tendinous fibres from the outer half or two-thirds of the lower border of the anterior annular ligament, and sometimes from the ridge of the trapezium, and is **inserted** into the outer side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon of insertion. This part of the muscle, partly concealed by the abductor pollicis, is superficial in the interval between that muscle and the tendon of the flexor longus pollicis.

b. The deep part of the muscle (interosseus primus volaris) **arises** from the ulnar side of the base of the first metacarpal bone, and is **inserted** into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus pollicis. This little muscle is deeply situated in the first interosseous space, in the interval between the adductor obliquus pollicis and the first dorsal interosseous muscle. It may be regarded as homologous with the palmar interossei muscles, with which it is in series.

The **adductor obliquus pollicis arises** by fleshy fibres from the anterior surfaces of the trapezium, trapezoid, and os magnum, from the sheath of the tendon of the flexor carpi radialis, from the basis of the second, third, and fourth metacarpal bones, and from the palmar ligaments connecting these bones together (Fig. 267, p. 346). It is **inserted** by a tendon, in which a sesamoid bone is developed, into the inner side of the base of the first phalanx of the thumb. At its outer border a slender slip separates from the rest of the muscle, and passing obliquely beneath the tendon of the flexor longus pollicis, is inserted into the outer side of the base of the first phalanx along with the superficial part of the flexor brevis pollicis.

The adductor obliquus pollicis lies on the ulnar side of the tendon of the flexor longus pollicis, internal to the thenar eminence. It is covered by the flexor tendons of the thumb and fingers, and conceals the radial artery and the deep part of the flexor brevis pollicis. At its inner border the radial artery (deep palmar arch) appears between it and the adductor transversus pollicis.

The **adductor transversus pollicis arises** by fleshy fibres from the median ridge

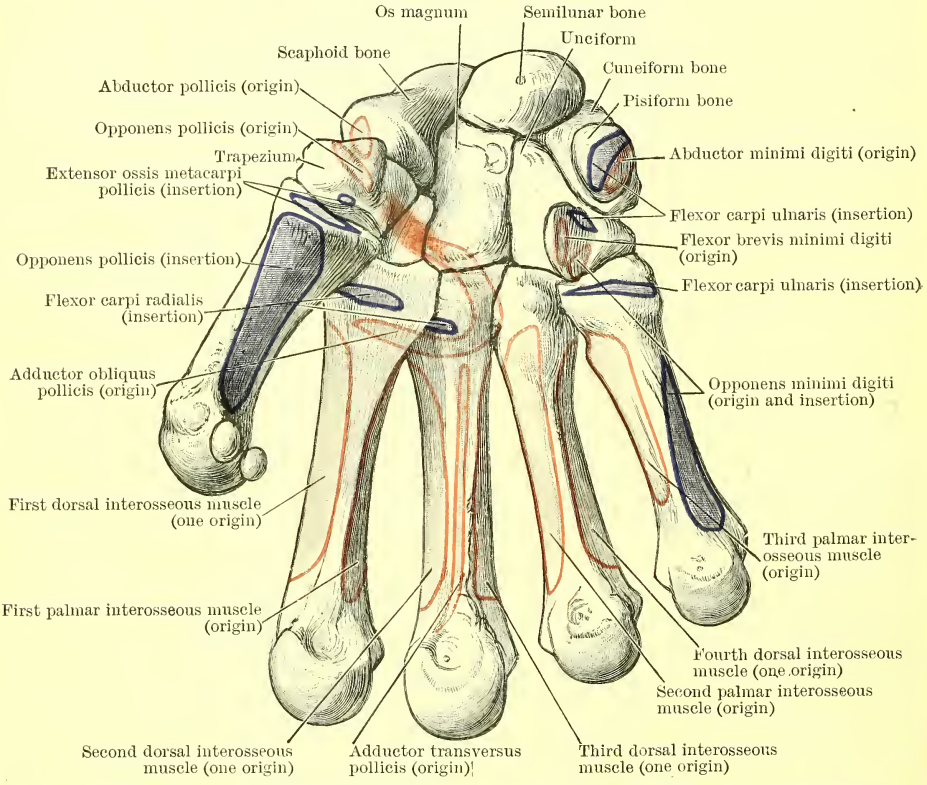


FIG. 267.—MUSCLE-ATTACHMENTS TO THE PALMAR ASPECT OF THE CARPUS AND METACARPUS.

on the front of the shaft of the third metacarpal bone, in its lower two-thirds (Fig. 267, p. 346), and from the fascia covering the interosseous muscles in the second and third spaces. Triangular in form, it is directed outwards, to be **inserted** by tendon into the inner side of the base of the first phalanx of the thumb along with the adductor obliquus. Lying deeply in the palm beneath the flexor tendons, this muscle conceals the interossei muscles of the first two spaces and the radialis indicis and princeps pollicis arteries. Its upper border is separated from the adductor obliquus pollicis by the radial artery (deep palmar arch).

MUSCLES OF THE LITTLE FINGER.

The short muscles of the little finger are three in number: abductor, opponens, and flexor brevis minimi digiti.

The **abductor minimi digiti** (m. abductor digiti quinti) **arises** from the front and inner side of the pisiform bone and from the tendon of the flexor carpi ulnaris and its ligamentous continuations (Fig. 267, p. 346), and is **inserted** by tendon into the inner side of the base of the first phalanx of the little finger. It lies superficially upon the opponens and flexor brevis minimi digiti.

The **opponens minimi digiti** (m. opponens digiti quinti) **arises** by tendinous fibres from the lower part of the anterior surface and from the lower border of the anterior annular ligament at its inner end, and from the lower border and inner side of the hook of the unciform bone, and is **inserted** into the inner margin and ulnar half of the palmar surface of the fifth metacarpal bone in its lower three-fourths (Fig. 267, p. 346).

It is concealed by the previous muscle, and may be pierced near its origin for the passage of the deep branches of the ulnar artery and nerve.

The **flexor brevis minimi digiti** (m. flexor digiti quinti brevis) **arises** by tendinous fibres from the inner part of the anterior surface of the anterior annular ligament and from the inner side of the hook of the unciform bone (Fig. 267, p. 346), and is **inserted** along with the abductor into the inner side of the first phalanx of the little finger.

This muscle is placed external to the opponens and abductor, and is separated from the latter by the deep branches of the ulnar artery and nerve. It may be reduced in size, absent altogether, or incorporated with either the opponens or abductor minimi digiti.

The Interosseous Muscles.

The interosseous muscles of the hand are arranged in two sets, palmar and dorsal.

The **palmar interossei** (m. interossei volares) are three in number, occupying the three inner interosseous spaces. Each **arises** by a single head; the *first* from the ulnar side of the shaft of the second metacarpal bone; the *second* and *third* from the radial sides of the shafts of the fourth and fifth metacarpal bones respectively (Fig. 267, p. 346). Each ends in a tendon which is directed downwards behind the deep transverse metacarpal ligament, to be **inserted** into the dorsal expansion of the extensor tendon, the capsule of the metacarpo-phalangeal articulation, and the side of the first phalanx of the finger; the *first* is **inserted** into the ulnar side of the second finger; the *second* and *third* into the radial sides of the fourth and fifth fingers. The deep part of the flexor brevis pollicis (interosseus primus volaris) is to be regarded as the homologous muscle of the first interosseous space.

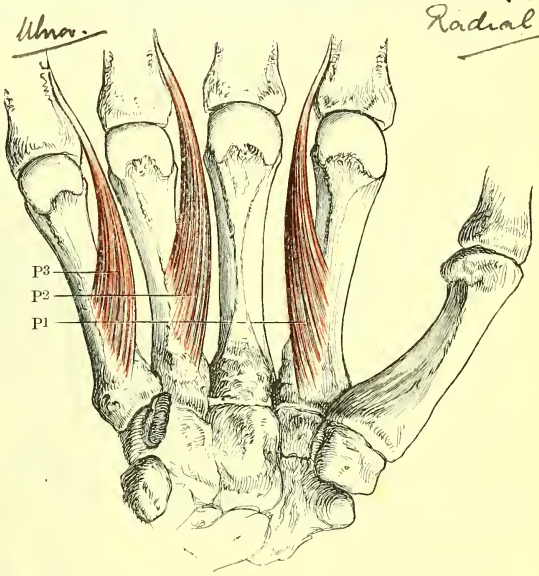


Fig. 268.—The Palmar Interosseous Muscles.
P¹, first; P², second; and P³, third palmar interosseous muscles.

The **dorsal interossei** are four in number. Each **arises** by two heads from the sides of the metacarpal bones bounding each interosseous space (Figs. 267, p. 346, and 269, p. 348). Each forms a fleshy mass, ending in a membranous tendon, which, passing downwards behind the deep transverse metacarpal ligament, is **inserted** exactly like the palmar muscles into the dorsal aspect of each of the four fingers. The insertion of the *first* dorsal interosseous muscle is into the radial side of the index finger; the *second* muscle is attached to the radial side of the

middle finger; the *third* muscle to the ulnar side of the same finger; and the *fourth* muscle to the ulnar side of the ring finger.

These muscles fill up the interosseous spaces; the dorsal interossei are visible

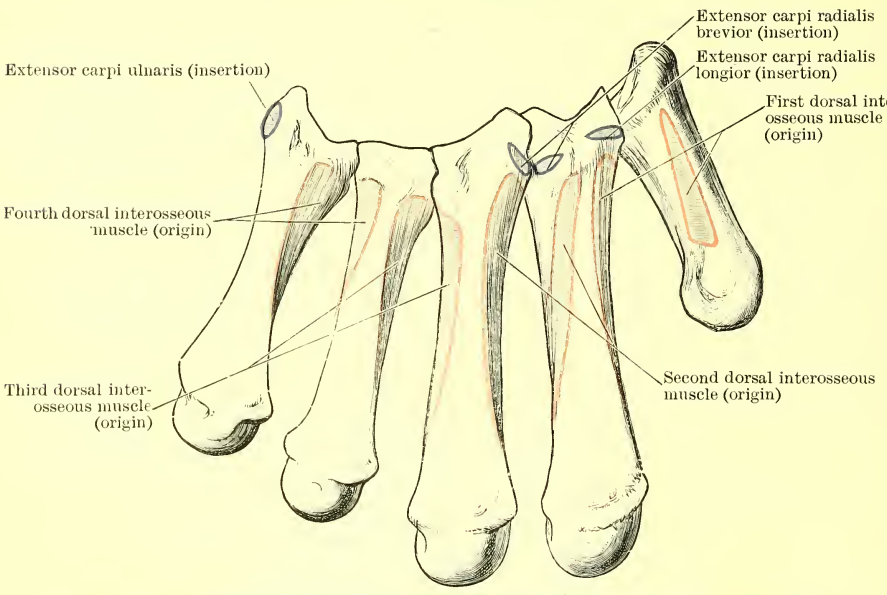


Fig. 269.—Muscle-Attachments to the Dorsal Aspect of the Metacarpus.

on the back of the hand when the extensor tendons are removed; in the palm the muscles are concealed by the flexor tendons and the muscles of the thumb and little finger, and are crossed by the deep palmar arch and the deep branch of the

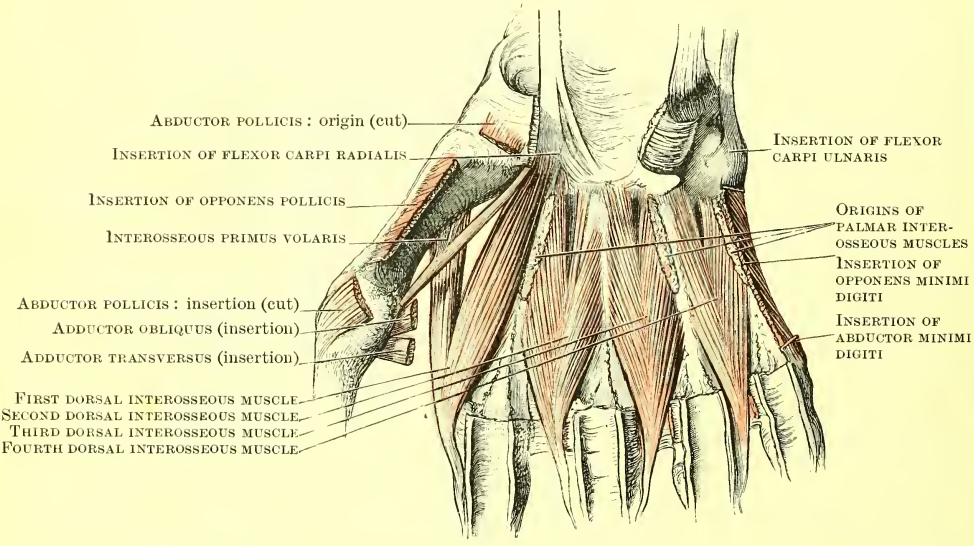


Fig. 270.—Dorsal Interosseous Muscles of the Hand (seen from the Palmar Aspect).

ulnar nerve. Between the two heads of the first dorsal muscle the radial artery enters the palm, and the perforating arteries pass between the heads of the other dorsal muscles.

The interossei muscles of the hand in some cases have a disposition similar to that of the corresponding muscles of the foot.

THE MUSCLES ON THE BACK OF THE FOREARM.

The group of muscles occupying the outer side of the elbow and the back of the forearm and hand include the supinator muscles of the forearm and the extensors of the wrist and digits. They are divisible into a **superficial** and a **deep layer.**

Superficial Muscles.

The **superficial layer** comprises seven muscles, viz. from without inwards, the brachio-radialis, the two radial extensors of the carpus, the extensor communis digitorum and extensor minimi digiti, the extensor capri ulnaris, and the anconeus.

The **brachio-radialis** (supinator radii longus) **arises** by fleshy fibres from the anterior aspect of the upper two-thirds of the external supra condyloid ridge of the humerus, and from the front of the external intermuscular septum (Fig. 257, p. 335). Occupying the outer side of the hollow of the elbow, the muscle descends along the outer border of the forearm, and ends about the middle in a narrow flat tendon which is **inserted** under cover of the tendons of the extensor ossis metacarpi pollicis and extensor brevis pollicis, by a transverse linear attachment, into the upper limit of the groove for the above-named muscles on the outer side of the lower extremity of the radius. Some of its fibres gain an attachment to the ridge in front of the groove, and others spread over the surface of the groove for a variable distance (Figs. 271, p. 351, and 264, p. 343).

The muscle is superficial in its whole length. Near its origin it is separated from the brachialis anticus by the musculo-spiral nerve. It forms the outer boundary of the hollow of the elbow, and conceals the radial extensors of the carpus, and, in the upper two-thirds of the forearm, the radial artery and nerve.

The **extensor carpi radialis longior** (m. ext. carp. rad. longus) **arises** by fleshy fibres from the lower third of the external supracondyloid ridge of the humerus on its anterior aspect, from the front of the external intermuscular septum, and from the common tendon of origin of succeeding muscles, which is attached to an impression on the antero-external surface of the external condyle (Figs. 257, and 258, p. 335). It ends in a tendon in the lower half of the forearm, which passes beneath the posterior annular ligament, to be **inserted** into the back of the base of the second metacarpal bone on its radial side (Fig. 269, p. 348).

The upper part of the muscle is concealed by the brachio-radialis, and the lower part is crossed by the extensors of the thumb. It covers the supinator radii brevis and extensor carpi radialis brevior above, and the back of the radius and the carpus below.

The **extensor carpi radialis brevior** (m. ext. carp. rad. brevis) **arises** from the common tendon, from the external lateral ligament of the elbow, from the fascia over it, and from intermuscular septa on each side. It passes down the back of the forearm and under the posterior annular ligament in close relation to the previous muscle, to be **inserted** by a tendon into the back of the base of the third metacarpal bone below the styloid process on its radial side. It usually has an additional insertion into the back of the base of the second metacarpal bone (Fig. 269, p. 348). A bursa is placed beneath the two radial extensor tendons close to their insertion.

Partially concealed by the extensor carpi radialis longior and the extensor muscles of the thumb, and having the extensor communis digitorum on its inner side, the muscle covers the supinator brevis, the lower part of the radius, and the back of the carpus.

The **extensor communis digitorum** **arises** from the common tendon, from the external condyle, from the fascia over it, and from intermuscular septa on each side. Extending down the back of the forearm it ends above the wrist in four tendons, of which the outermost often has a separate fleshy belly. After passing beneath the posterior annular ligament in a compartment along with the extensor indicis, the tendons separate on the back of the hand, where the three innermost tendons are joined together by two obliquely-placed bands. One passes downwards and outwards, and connects together the third and second tendons; the other is a broader

and shorter band, which passes also downwards and outwards, and joins the fourth to the third tendon. In some cases (Fig. 257) a third band is present, which passes downwards and inwards from the first to the second tendon; and frequently the tendon for the little finger is joined to the tendon for the ring finger, and separates from it only a short distance above the lower end of the metacarpal bone.

The tendons are **inserted** in the following manner: On the finger each tendon spreads out so as to form a membranous expansion over the knuckle and on the back of the first phalanx. The border of the tendon is indefinite over the metacarpo-phalangeal articulation, of which it forms the posterior ligament. On the back of the first phalanx the tendon receives laterally the insertions of the interossei and lumbrical muscles. At the lower end of the first phalanx the tendon splits into ill-defined median and lateral slips, proceeding over the back of the first inter-phalangeal articulation, of which they form the posterior ligament. The median slip is inserted into the back of the base of the second phalanx, while the two lateral pieces become united to form a membranous tendon on the back of the second phalanx, which, after passing over the second inter-phalangeal articulation, is inserted into the base of the terminal phalanx.

The extensor communis digitorum is superficial in its whole length, and lies in the upper part of the forearm between the radial extensors of the carpus externally and the extensor minimi digiti internally. It conceals the supinator brevis and other deep muscles of the forearm, as well as the posterior interosseous vessels and nerves. The extensors of the thumb become superficial along its outer border in the lower third of the forearm.

The **extensor minimi digiti** (m. extensor digiti quinti proprius) has an **origin** similar to and closely connected with that of the preceding muscle, from the common tendon, the fascia over it, and lateral intermuscular septa. Passing down the back of the forearm as a narrow fleshy slip, between the extensor communis digitorum and the extensor carpi ulnaris, it ends in a tendon which occupies a groove between the radius and ulna in a special compartment of the posterior annular ligament. On the back of the hand the tendon, usually split into two parts, lies internal to the tendons of the extensor communis digitorum, and is finally **inserted** into the expansion of the extensor tendon on the dorsum of the first phalanx of the little finger.

The **extensor carpi ulnaris** has a double **origin**: (1) from the common tendon from the external condyle of the humerus, from the fascia over it, and from the intermuscular septa; and (2) through the medium of the deep fascia, from the posterior border of the ulna in its middle two-fourths. The muscle ends in a tendon in the lower third of the forearm, which occupies a groove on the back of the ulna in a special compartment of the posterior annular ligament, and is **inserted** into the ulnar side of the base of the fifth metacarpal bone (Fig. 269, p. 348).

The muscle is superficially placed between the extensor minimi digiti and the anconeus, external to the posterior border of the ulna. It conceals the supinator radii brevis and the posterior interosseous vessels and nerve above, and in the lower two-thirds of the forearm it lies upon the posterior surface of the ulna.

The **anconeus** is a small triangular muscle **arising** by a separate tendon from the lower part of the back of the external condyle of the humerus (Fig. 258, p. 335), and from the posterior ligament of the elbow-joint. Spreading out over the ulna, it is **inserted** by fleshy fibres into a triangular surface on the outer side of the olecranon process and back of the ulna, as low down as the oblique line (Fig. 271, p. 351). It is also inserted into the fascia which covers it.

It is covered by the thickened fascia of the forearm giving insertion to the triceps muscle. It conceals the back of the elbow-joint and part of the origin of the supinator brevis muscle.

The **epitrochleo-anconeus** is an occasional small muscle **arising** from the back of the internal condyle of the humerus, and **inserted** into the inner side of the olecranon process. It covers the ulnar nerve in its passage to the forearm.

Deep Muscles.

The **deep muscles** on the back of the forearm comprise five muscles, of which

one, the supinator radii brevis, extends between the ulna and radius; the others are extensors of the thumb and forefinger: the extensor ossis metacarpi pollicis, extensor brevis and extensor longus pollicis, and extensor indicis.

The **supinator radii brevis** (m. supinator) muscle has a complex **origin**. It **arises** by fleshy and tendinous fibres: (1) from the external condyle of the humerus; (2) from the external lateral and orbicular ligaments of the elbow-joint; (3) from the triangular surface on the shaft of the ulna just below the lesser sigmoid cavity; and (4) from the fascia over it. From this origin the muscle spreads outwards and downwards, enveloping the upper part of the radius, and is **inserted** into the anterior and outer surfaces of the bone, as far forwards as the bicipital tubercle, as far upwards as the neck, and as far downwards as the oblique line and the insertion of the pronator radii teres. The insertion of the muscle in some cases encroaches for a variable distance on to the posterior surface of the shaft of the radius above the origin of the extensor ossis metacarpi pollicis; but the neck and the inner half of the posterior surface of the shaft are left without muscular attachment (Figs. 271, p. 351, and 264, p. 343).

The supinator brevis is deeply placed, and is uncovered only anteriorly in the hollow of the elbow. It is covered by all the superficial muscles on the back of the forearm. It conceals the back of the elbow-joint and the upper part of the radius. At its lower border is the extensor ossis metacarpi pollicis, separated from it by the posterior interosseous artery. The muscle is divisible into *superficial* and *deep parts* with humeral and ulnar origins, between which the posterior interosseous nerve passes in its course to the back of the forearm.

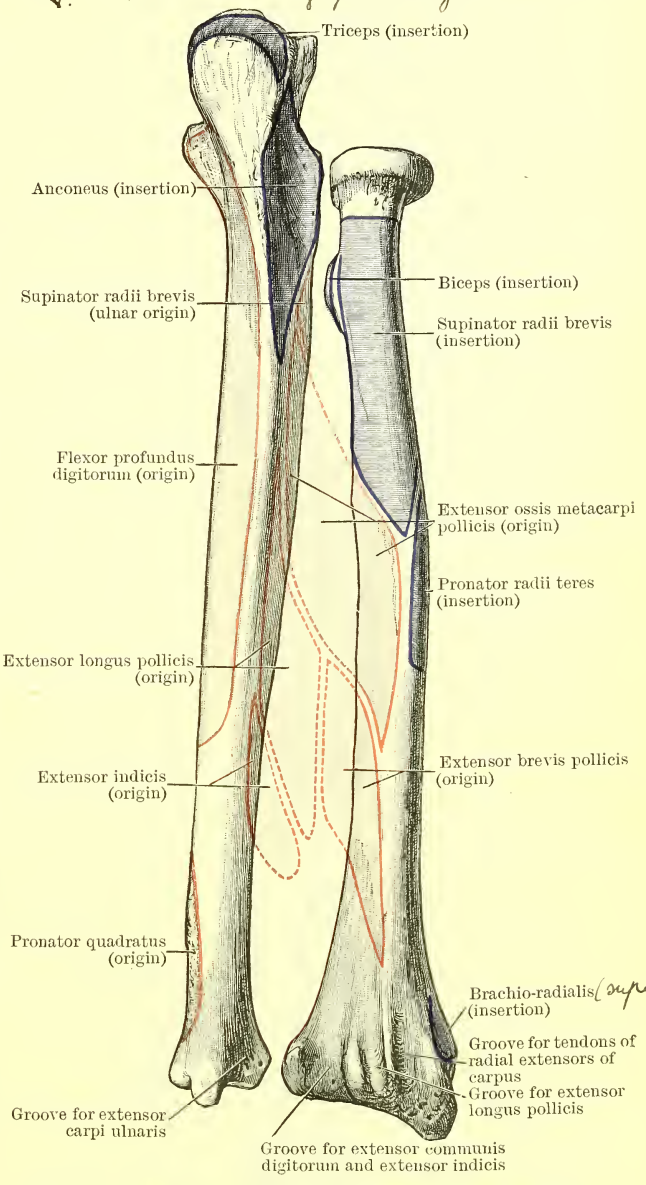


FIG. 271.—MUSCLE-ATTACHMENTS TO THE RADIUS AND ULNA (Posterior Aspects).

The **extensor ossis metacarpi pollicis** (m. abductor pollicis longus) **arises** by fleshy fibres below the supinator brevis from the posterior or extensor surfaces of the shafts of the radius and ulna; from the uppermost of the narrow impressions on the outer half of the posterior surface of the ulna; from the middle third of the posterior surface of the radius; and from the intervening portion of the interosseous membrane (Fig. 271, p. 351). Becoming superficial in the lower part of the forearm along with the extensor brevis pollicis, its tendon passes with that

muscle beneath the posterior annular ligament, to be **inserted** into the outer side of the base of the first metacarpal bone (Fig. 267, p. 346). From the tendon close to its insertion a tendinous slip passes to the abductor pollicis and the fascia over the thenar eminence, and another is frequently attached to the trapezium.

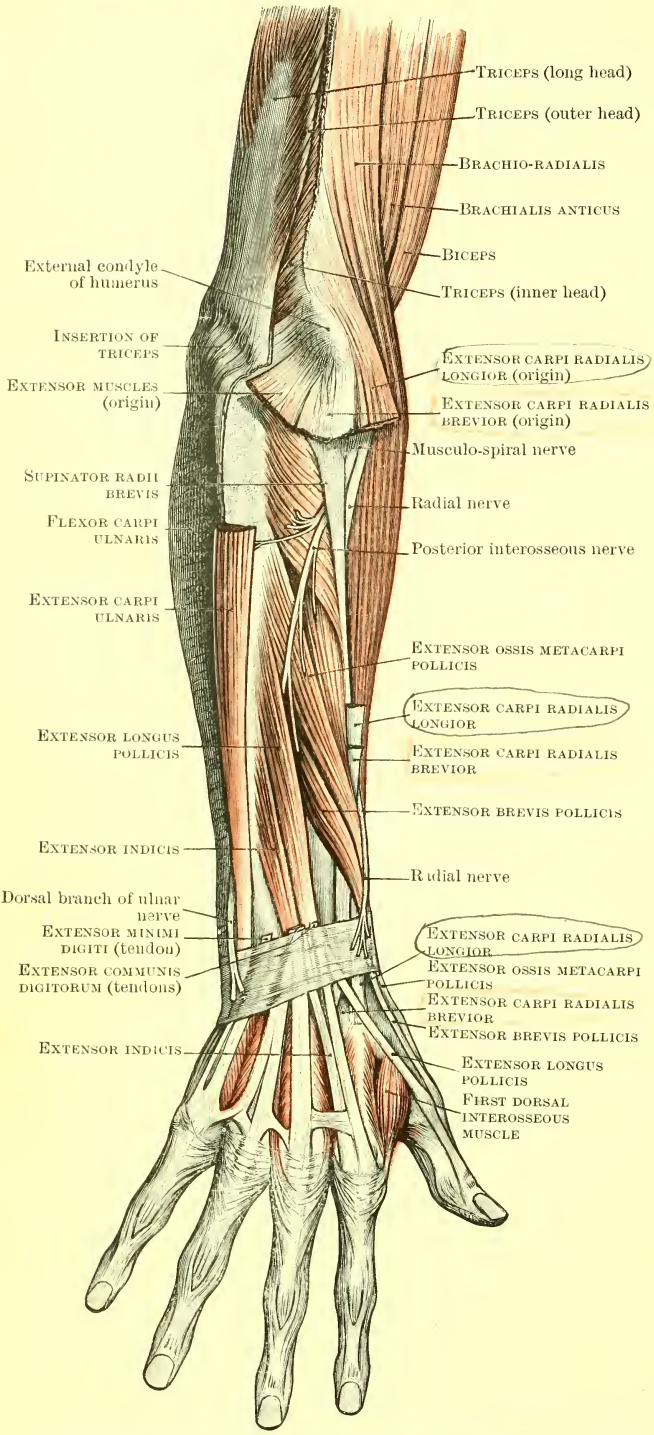


Fig. 272.—The Muscles of the Back of the Forearm (the superficial muscles being reflected).

At its origin the muscle is deeply placed beneath the superficial extensor muscles and the posterior interosseous vessels and nerve. Above is the supinator brevis; below and internally, the long and short extensors of the thumb. In the lower third of the forearm it becomes superficial along with the extensor brevis pollicis, between the extensor communis digitorum and the radial extensors of the carpus. It covers the last-named muscles in its further course in the forearm, and at the outer side of the carpus it crosses the radial artery.

The **extensor brevis pollicis** (extensor primi internodii pollicis), an essentially human muscle, is a specialised portion of the previous muscle. It **arises** from a rhomboid impression on the posterior surface of the radius, extending from the middle of the bone to within an inch and a half of the lower end, and from the interosseous membrane, below the extensor ossis metacarpi pollicis (Fig. 271, page 351). It is closely adherent to that muscle, and accompanies it beneath the posterior annular ligament and over the radial artery to the thumb. Its tendon is then continued along the back of the first metacarpal bone, and the metacarpophalangeal articulation, to be **inserted** into the back of the base of the first phalanx of the thumb. Before reaching its insertion the tendon helps to form the capsule

of the metacarpo-phalangeal joint. In the forearm the muscle is deeply placed beneath the superficial extensors, and is separated from the extensor longus pollicis by the posterior interosseous nerve.

The **extensor longus pollicis** (extensor secundi internodii pollicis) **arises** from the intermediate impression occupying the outer part of the posterior or extensor surface of the ulna in its middle third, and from the interosseous membrane, below the extensor ossis metacarpi pollicis (Fig. 271, p. 351). Its tendon grooves the back of the radius, and occupies a special compartment beneath the posterior annular ligament. Extending obliquely across the back of the hand, it is **inserted** into the dorsal surface of the base of the second phalanx of the thumb.

The muscle is deeply placed beneath the superficial extensors of the forearm, and lies between the extensor brevis pollicis and the extensor indicis. It separates the posterior interosseous artery from the nerve, the latter passing beneath it. On the back of the hand the tendon crosses the radial artery, and helps to form the capsule of the first metacarpo-phalangeal articulation.

At the wrist the tendons of the muscles of the thumb, the extensor ossis metacarpi pollicis and extensor brevis pollicis externally, and the extensor longus pollicis internally, bound a hollow (the "anatomical snuff-box") best seen in extension and abduction of the thumb, which corresponds to the position of the radial artery as it winds round the wrist to reach the palm of the hand.

The **extensor indicis** (m. extensor indicis proprius) **arises** by fleshy fibres below the extensor longus pollicis from the lowest impression on the back of the ulna, extending down from the middle of the shaft to within two inches of its lower end, and sometimes also from the interosseous membrane (Fig. 271, p. 351). Its tendon passes through a compartment of the posterior annular ligament along with the tendons of the extensor communis digitorum, and is **inserted** into the forefinger joining the membranous expansion of the tendon of the extensor communis digitorum on the dorsum of the first phalanx.

Lying deeply in the forearm, the muscle is placed internal to the extensor longus pollicis, and covers the posterior interosseous nerve. On the back of the hand its tendon lies on the inner side of the tendon of the common extensor destined for the forefinger.

Nerve-Supply.

Four nerves are engaged in supplying the muscles of the forearm and hand—the median and ulnar on the front, the musculo-spiral and posterior interosseous nerves on the back of the limb.

Muscles.	Nerves.	Origin.
A. Anterior Muscles of the Forearm.		
Pronator radii teres Flexor carpi radialis Palmaris longus Flexor sublimis digitorum	Median	C. 6.
Flexor carpi ulnaris	Ulnar	C. 8. T. 1.
Flexor profundus digitorum	Ulnar and Anterior interosseous (median)	C. 8. T. 1. C. 7. 8. T. 1.
Flexor longus pollicis Pronator quadratus	Anterior interosseous	C. 7. 8. T. 1.
B. Muscles of the Hand.		
Abductor pollicis Opponens pollicis Flexor brevis pollicis (superficial)	Median	C. 6. 7.
Flexor brevis pollicis (deep) Adductor obliquus pollicis Adductor transversus pollicis	Ulnar	C. 8. (T. 1).
Lumbricales 1st and 2nd	Median	C. 6. 7.
Lumbricales 3rd and 4th Interossei Flexor brevis minimi digiti Opponens minimi digiti Abductor minimi digiti	Ulnar	C. 8. (T. 1).

Muscles.	Nerves.	Origin.
C. Posterior Muscles of the Forearm.		
Brachio-radialis	Musculo-spiral . .	C. 5. 6.
Extensor carpi radialis longior		C. 6. 7.
Extensor carpi radialis brevior		C. 6. 7.
Extensor communis digitorum	Posterior interosseous (musculo-spiral)	C. 6. 7. 8.
Extensor minimi digiti		
Extensor carpi ulnaris		
Anconeus	Musculo-spiral . .	C. 7. 8.
Supinator radii brevis		C. 6.
Extensor ossis metacarpi pollicis		
Extensor brevis pollicis	Posterior interosseous .	C. 6. 7. 8.
Extensor longus pollicis		
Extensor indicis		

Action of the Muscles of the Forearm and Hand.

The muscles of the forearm and hand are concerned in the movements of the elbow, wrist, and fingers.

In the majority of cases the muscles act upon more than one joint.

1. Action on the Elbow-Joint.—It has been shown already that flexion and extension of the elbow are assisted by certain of these muscles. The **flexor muscles** are the pronator radii teres, and the flexor muscles of the wrist and fingers. In the position of pronation, the movement of flexion is aided by the brachio-radialis and extensors of the wrist and fingers. The **extensors** are the supinator brevis and anconeus, and the extensor muscles of the wrist and fingers.

2. Pronation and supination of the hand are performed by special muscles, aided by muscles which act also upon other joints. The brachio-radialis assists in flexion and pronation on the one hand, and in extension and supination on the other hand. In the supine position it assists pronation, and in the prone position it assists supination, in each case bringing the hand into the position intermediate between pronation and supination.

Pronation.	Supination.
Pronator radii teres	Supinator radii brevis
Pronator quadratus	Biceps
Brachio-radialis	Brachio-radialis
Flexor carpi radialis	Extensors of thumb and fingers
Weight of the limb	Weight of the limb

3. Action on the Wrist-Joint.—The movements at the wrist-joint are flexion and extension, abduction and adduction. Flexion and adduction are much more extensive movements than extension and abduction, on account of the form of the wrist-joint. The following muscles produce these movements:—

Flexion.	Extension.	Adduction.	Abduction.
Flexor carpi radialis	Extensors of the wrist	Flexor carpi ulnaris	Flexor carpi radialis
Palmaris longus	Extensors of thumb and fingers	Extensor carpi ulnaris	Extensors of wrist
Flexor carpi ulnaris			Extensors of thumb
Long flexors of thumb and fingers			

4. Movements of the Fingers.—Two separate series of movements occur in relation to the articulations of the fingers: flexion and extension (at the metacarpo-phalangeal and inter-phalangeal joints), and abduction and adduction (only at the metacarpo-phalangeal joints). The movements and the muscles concerned are given in the following tables:—

Flexion.	Extension.
Flexor sublimis digitorum	Extensor communis digitorum
Flexor profundus digitorum	Extensor indicis
Lumbricales (*acting on the metacarpo-phalangeal articulations*)	Extensor minimi digiti
Interossei	Lumbricales (*acting on the inter-phalangeal articulations*)
Flexor brevis minimi digiti	Interossei

Abduction.	Adduction.
Lumbricales Flexor brevis and Opponens minimi digiti (from the inner side of the hand) Dorsal interossei (from the middle line of the middle finger)	Palmar interossei (to the middle line of the middle finger)

Flexion is more powerful and complete than extension of the fingers. The flexor profundus digitorum alone acts on the terminal phalanges; the flexor sublimis and flexor profundus together flex the proximal inter-phalangeal joint; and flexion of the metacarpo-phalangeal articulation is effected by these muscles, assisted by the interossei, lumbricales, and flexor brevis minimi digiti. Extension of the phalanges is effected by the united action of the extensors of the digits, the interossei and lumbricales; extension of the fingers at the metacarpo-phalangeal joints is produced solely by the long extensor muscles. *Separate extension of the index finger* only is possible; the three inner fingers can only be flexed and extended together, on account of the connecting bands joining the extensor tendons together on the back of the hand.

5. Movements of the Thumb.—The movements of which the thumb is capable are flexion and extension (occurring at the carpo-metacarpal, metacarpo-phalangeal, and inter-phalangeal joints); abduction and adduction, together with circumduction (occurring at the carpo-metacarpal joint).

The muscles and their respective actions are given in the following table:—

Flexion.	Extension.
Opponens pollicis (carpo-metacarpal joint) Flexor brevis, Adductors, Abductor (carpo-metacarpal and metacarpo-phalangeal joint) Flexor longus pollicis (all joints)	Extensor ossis metacarpi pollicis (carpo-metacarpal joint) Extensor brevis pollicis (carpo-metacarpal and metacarpo-phalangeal joint) Extensor longus pollicis (all joints)
Adduction.	**Abduction.**
Adductors of the thumb Flexor brevis, Opponens pollicis First dorsal interosseous	Abductor pollicis Extensors of the thumb
Circumduction—a combination of the above muscles.	

The characteristic features of the movements of the upper limb are their range and refinement. The hand, in addition to its intrinsic powers, can be moved through a wide range and in several planes by the muscles acting on the wrist and radio-ulnar joints; this range is increased by the fore and aft movements at the elbow-joint, and the extensive movements of which the shoulder and clavicular joints are capable. The result is that the hand can be brought into a position to cover and guard any portion of the body. The precision and refinement of movement is made possible by the co-ordinate movements of the various muscles acting upon the several joints, so that actions can be performed (as raising the food to the mouth) in which all the articulations of the limb are brought into play; while others (such as writing) are possible by movements at the joints of the wrist and fingers along with fixation of the elbow-joint.

THE LOWER LIMB.

FASCIÆ AND MUSCLES OF THE THIGH AND BUTTOCK.

FASCIÆ.

The **superficial fascia** of the thigh and buttock is continuous above with the fascia of the abdomen and back, internally with that of the perineum, and below with that of the leg. It presents noticeable features in the buttock and groin.

In the buttock the superficial fascia is of considerable thickness, and is usually loaded with fat, whereby it assists in forming the contour of the buttock and the fold of the nates.

In the groin it is divisible into *two layers*: a **superficial fatty layer**, continuous with a similar layer on the front of the abdominal wall above, and over the perineum internally, and a **deeper membranous layer**, which is attached above to the inner half of Poupart's ligament, and to the deep fascia of the thigh just below the outer half of that ligament. Internally it is attached to the pubic arch, and below the level of Scarpa's triangle it blends inseparably with the superficial fatty layer. The separation of these two layers of the superficial fascia is occasioned by the presence between them of the femoral and inguinal lymphatic glands, the internal saphenous vein and its tributaries, and some small arteries. The attachment of the deeper layer of the fascia to the pubic arch and Poupart's ligament cuts off the superficial tissues of the thigh from the perineum and the anterior abdominal wall, and prevents the passage down the thigh of fluid collected in the perineum or beneath the fascia of the anterior abdominal wall.

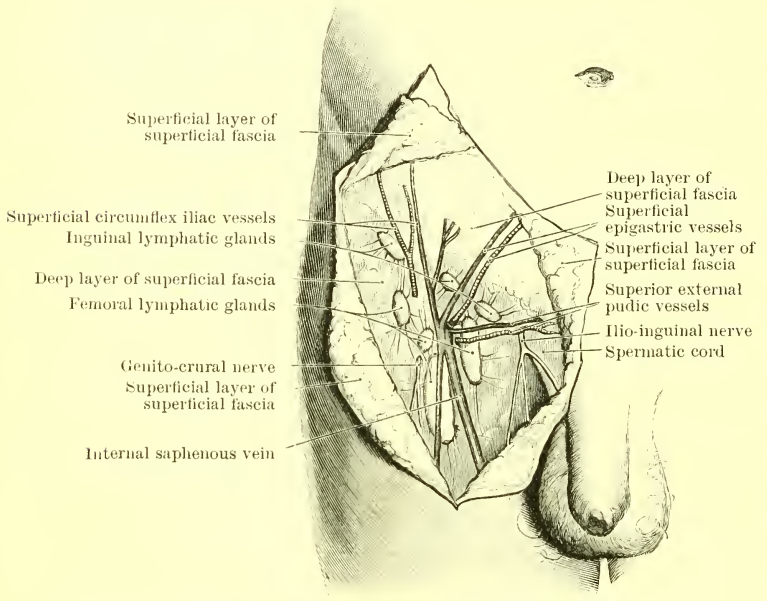


FIG. 273.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **deep fascia** or **fascia lata** forms a tubular investment for the muscles and vessels of the thigh and buttock. It is firmly attached above to the iliac crest, the great sacro-sciatic ligament, the ischium, the pubic arch, the pubic symphysis and crest, and Poupart's ligament. Below, in relation to the knee, it is continuous with the deep fascia of the leg, gains attachment to the patella, the tuberosities of the tibia and the head of the fibula, and forms the lateral ligaments of the patella.

On the front of the thigh the deep fascia is thick and strong. It is pierced by numerous openings for vessels and nerves, the most important of which is the **saphenous opening** for the internal saphenous vein. A femoral hernia passes through this opening to reach the front aspect of the anterior abdominal wall. It is an oval opening of variable size situated just below the inner half of Poupart's ligament, and immediately in front of the femoral vessels. It is covered by the superficial fascia, and by a special layer of fascia, the **cribriform fascia**, a thin perforated lamina, attached to the margins of the opening. The outer edge of the opening is formed by the margin of the *iliac portion* of the fascia lata, which is attached above to the iliac crest and Poupart's ligament; the inner edge is formed by the *pubic portion* of the fascia lata, which is continued upwards behind the femoral sheath, over the adductor longus and pectineus muscles to the ilio-pectineal line and the capsule of the hip-joint. These two layers of the fascia lata are continuous at the lower concave margin of the saphenous opening, forming its **inferior cornu**. As they pass upwards towards the pelvis they occupy different planes, the iliac portion being in front of the femoral sheath, while the pubic portion of the fascia is behind it. The **superior cornu** of the saphenous opening,

placed in front of the sheath, is derived solely from the iliac portion of the fascia lata. It forms a strong triangular band of fascia attached above to the inner half of Poupart's ligament, and is known as the **falciform ligament**. It has an important share in directing the course of a femoral hernia upwards on to the abdominal wall.

Internally in relation to the adductor muscles of the thigh the fascia lata becomes much thinner. *At the knee* it is associated with the tendons of the vasti muscles, and forms the **lateral ligaments of the patella**, attached to the borders of the patella and to the tuberosities of the tibia. *Externally* it gives rise to the

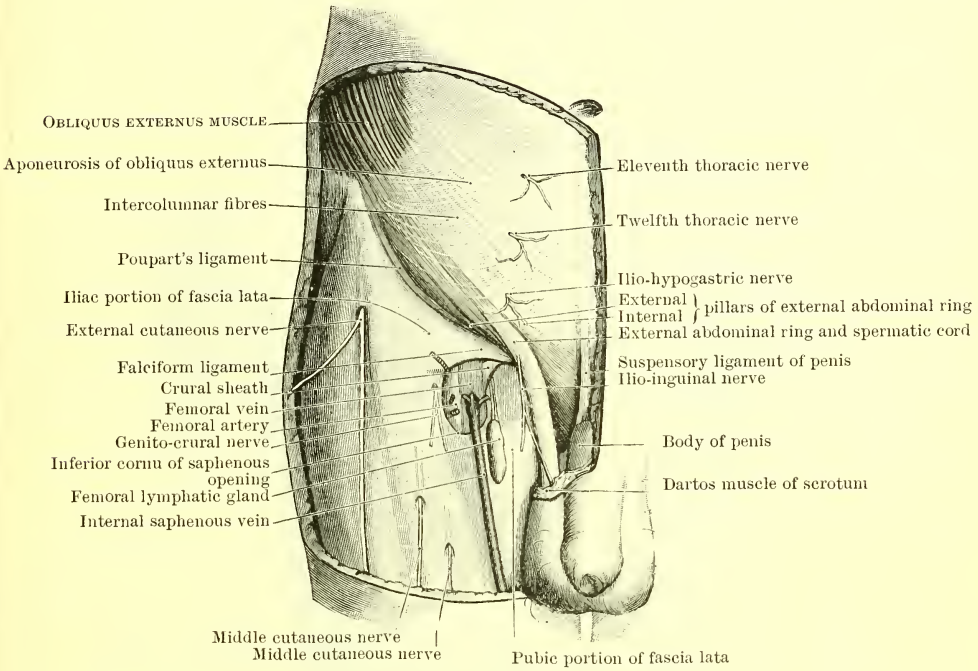


Fig. 274.—The Groin—the Structures seen on removal of the Superficial Fascia.

ilio-tibial band—a broad thick layer of fascia which is attached above to the iliac crest, and receives the insertions of two muscles in the upper part of the thigh—the tensor fasciæ femoris, and part of the gluteus maximus; it is attached below to the capsule of the knee-joint and the outer tuberosity of the tibia. The fascia beneath the tensor fasciæ femoris muscle, continued upwards from the ilio-tibial band, sends a strong band inwards which joins the origin of the rectus femoris and the capsule of the hip-joint.

On either side of the thigh above the knee an intermuscular septum is formed; the **external intermuscular septum** extends inwards from the ilio-tibial band to the external supra-condyloid ridge and linea aspera of the femur, and gives attachment to the vastus externus and crureus in front, and the short head of the biceps behind. The **internal intermuscular septum** is more complex. It is represented by a layer of fascia which forms separate envelopes for the gracilis and sartorius muscles, and in the upper and middle thirds of the thigh encloses the adductor muscles. In the middle third of the thigh the fascia is specially thickened by transverse fibres connecting together the adductor muscles and the vastus internus. This sheet of fascia forms a special aponeurosis beneath the sartorius, which roofs over the femoral artery in Hunter's canal. In the lower third of the thigh the intermuscular septum is closely associated with, and is to a large extent represented by, the tendon of the adductor magnus muscle.

The **fascia lata of the buttock** is thick anteriorly where it covers and gives origin to the gluteus medius, thinner posteriorly over the gluteus maximus, at the upper border of which it splits to enclose the muscle. It is greatly thickened over the

region of the great trochanter, where it forms the insertion of the greater part of the same muscle.

On the **back of the thigh** and over the **popliteal space** the fascia is strengthened by transverse fibres derived from the hamstring muscles. The **popliteal fascia**

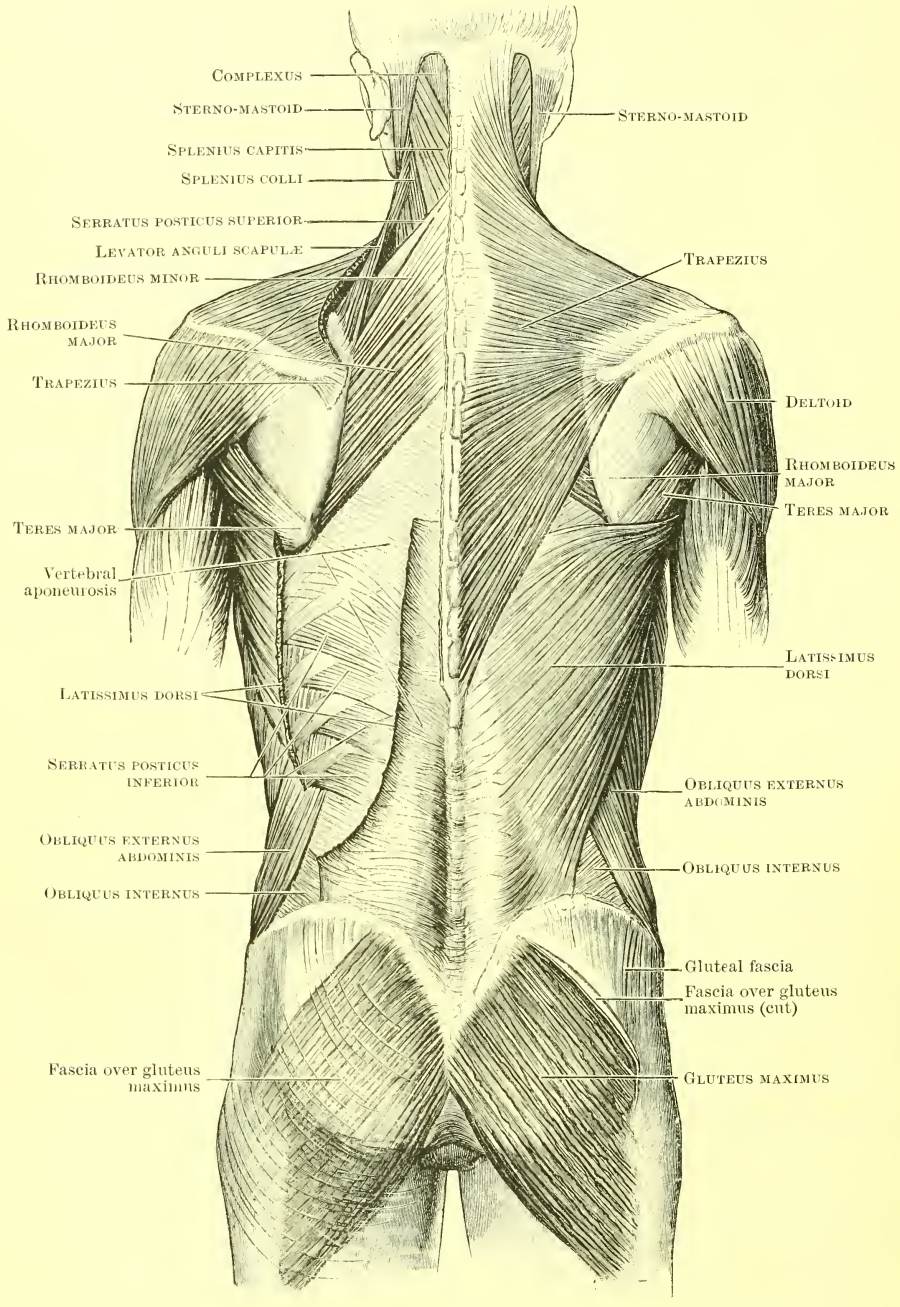


Fig. 275.—Superficial Muscles of the Back.

forming the roof of the popliteal space is specially thick, and is usually pierced by the external saphenous vein.

A **femoral hernia** appears in the thigh through the saphenous opening, thereafter passing upwards over Poupart's ligament to the anterior abdominal wall.

Femoral Sheath.—This is a conical membranous investment for the femoral vessels, prolonged into Scarpa's triangle beneath Poupart's ligament, and con-

tinuous above with the internal fascial lining of the abdominal wall, formed by the fascia transversalis in front and the fascia iliaca behind. The sheath is divided into three compartments—an external space for the artery, an intermediate space for the vein, and an internal channel containing lymphatics, and named the **crural canal**. The wall of this is known as the **crural sheath**. This canal is the passage through which a femoral hernia enters the thigh. Its upper limit is the **crural ring**, placed behind Poupart's ligament in front of the origin of the pectineus muscle from the pubis; it is bounded internally by Gimbernat's ligament, and externally by the femoral vein. In front of it the fascia transversalis forming the sheath is thickened to form the **deep crural arch**. The part of Poupart's ligament in front of the ring is called the **superficial crural arch**. The deep epigastric artery separates the crural ring from the internal abdominal ring. The crural canal ordinarily contains fat which is continuous above with the extra-peritoneal tissue. The crural ring is filled by a plug of fat or a lymphatic gland, constituting the **crural septum**.

The crural canal ends behind the saphenous opening, covered by the cribriform fascia; the falciform ligament crosses over it and conceals its upper portion. The course of a femoral hernia is determined by this band of the fascia lata. The hernia descends through the crural ring, pushing the crural septum before it; it traverses the crural canal, and is directed forwards through the saphenous opening. The anterior part of the hernia being pressed upon and retarded by the crural arches and by the falciform ligament, the posterior part pushes onwards, hooks round the falciform ligament, and is directed upwards over Poupart's ligament. The coverings of a femoral hernia, in addition to peritoneum and extra-peritoneal tissue (crural septum), are crural sheath, cribriform fascia, superficial fascia, and skin.

THE MUSCLES ON THE FRONT OF THE THIGH.

The muscles on the front of the thigh include the sartorius, quadriceps extensor, ilio-psoas, and pectineus muscles.

The **sartorius**, a long strap-like muscle stretching obliquely across the thigh, **arises** by short tendinous fibres from the anterior superior spine of the ilium and half of the notch below it (Fig. 285, p. 369). It passes down the thigh to the inner side of the knee, where it is **inserted** by aponeurotic fibres into the inner surface of the shaft of the tibia just below the inner tuberosity, and by its borders into fascial expansions which join the capsule of the knee-joint and the fascia lata of the leg (Fig. 279, p. 363). An expansion from the upper part of the tendon of insertion is attached along an oblique line, which is directed downwards and backwards, above the attachment of the gracilis, to the internal lateral ligament of the knee-joint, with which it is connected.

The sartorius is superficial in its whole extent. It is so twisted on itself that in the upper third of its length its superficial surface looks forwards, in the lower third inwards, at the side of the knee. It passes diagonally down the thigh, separating the quadriceps extensor externally from the adductor muscles internally. Its upper third forms the outer boundary of Scarpa's triangle; its middle third forms the roof of Hunter's canal; and its lower third, in contact with the inner side of the knee, is separated from the tendon of the gracilis muscle by the long saphenous nerve and a branch of the anastomotic artery. A bursa lies beneath the tendon at its insertion. The sartorius conceals in its upper third the external circumflex vessels and branches of the anterior crural nerve, and it covers the femoral vessels in Hunter's canal.

The **quadriceps extensor** (m. quadriceps femoris) lies between the sartorius on the one hand and the tensor fasciæ femoris and ilio-tibial band on the other; it is composed of four muscles—the rectus femoris, vastus externus, crureus, and vastus internus.

The **rectus femoris** has a double tendinous **origin**. (1) The *straight head* arises from the anterior inferior spine of the ilium (Fig. 282, p. 366); (2) the *reflected head* springs from a rough groove on the dorsum ilii just above the highest part of the acetabulum (Fig. 285, p. 369). A bursa lies beneath this

head of origin. The two heads, bound together and connected to the capsule of the hip-joint by a band of fascia derived from the under surface of the tensor fasciæ femoris (ilio-tibial band), give rise to a single tendon which extends for

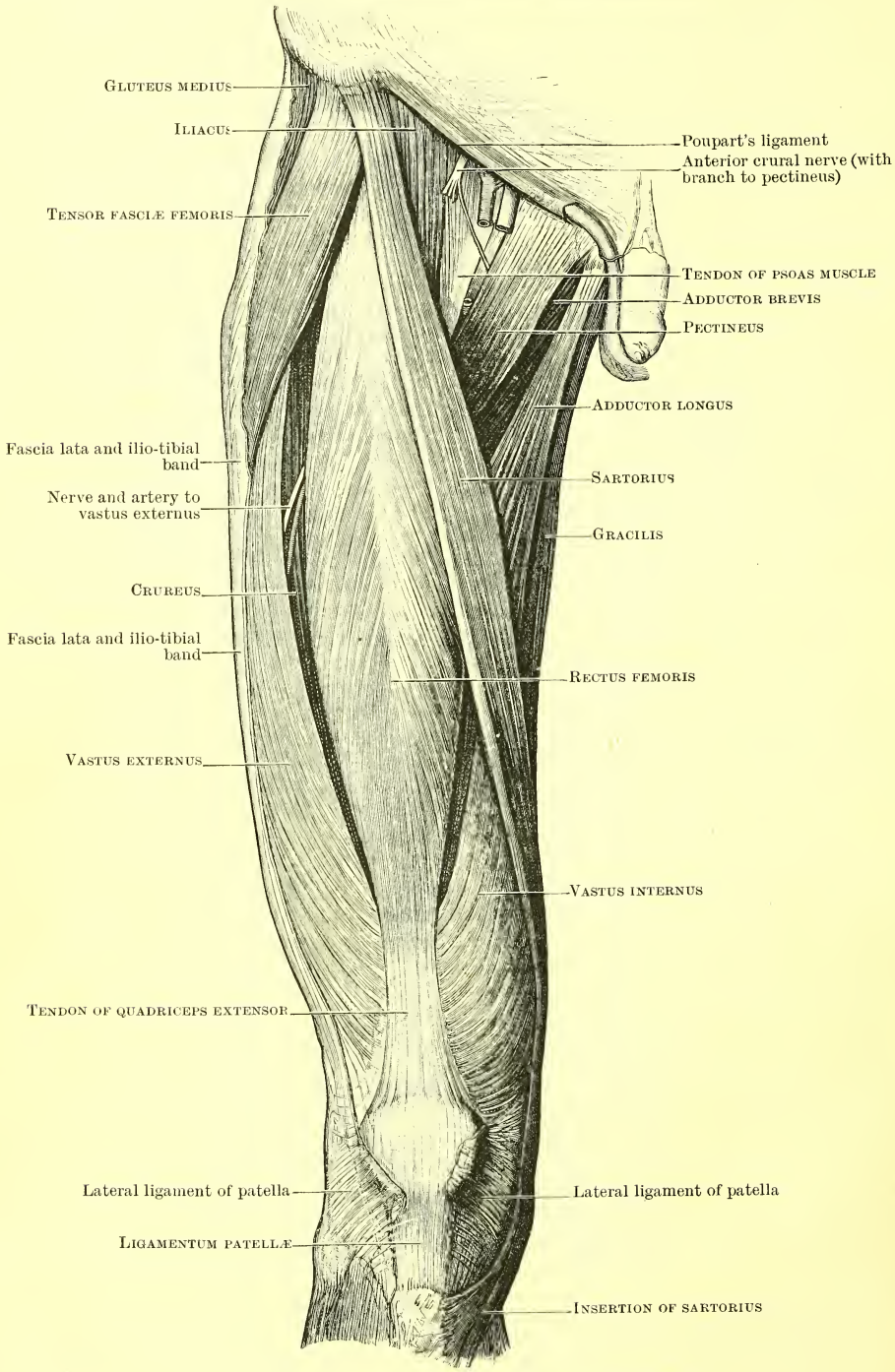


Fig. 276.—The Muscles on the Front of the Thigh.

some distance on the front of the muscle, and from which the muscular fibres arise. The muscular fibres springing from this tendon, and also from a median septal tendon, present a bipennate arrangement, and end below in a broad tendon which passes upwards for some distance along the posterior surface of the muscle. This

tendon gradually narrows towards the knee, and spreading out again, is **inserted** into the upper border of the patella. It receives laterally parts of the insertions of the vasti muscles, and on its deep surface is joined by the tendinous insertion of the crureus.

The rectus femoris is superficial except at its origin, which is covered by the glutei, tensor fasciæ femoris, and sartorius muscles. On its inner side lie the iliacus, sartorius, and vastus internus; on its outer side are the tensor fasciæ femoris and vastus externus. It conceals the crureus muscle and branches of the external circumflex artery and anterior crural nerve. A bursa, which communicates with the synovial membrane of the knee-joint, lies beneath its tendon in front of the lower end of the shaft of the femur.

The **vastus externus** (m. vastus lateralis) has an **origin**, partly fleshy, partly membranous, (1) (slightly) from the capsule of the hip-joint, (2) from the tubercle of the femur, (3) from a concave surface on the front of the shaft of the bone internal to the great trochanter, (4) from the lower border of the great trochanter, (5) from the outer margin of the gluteal ridge of the femur and the tendon of the gluteus maximus, (6) from the upper half of the linea aspera, and (7) from the fascia lata and external intermuscular septum (Fig. 277, p. 361).

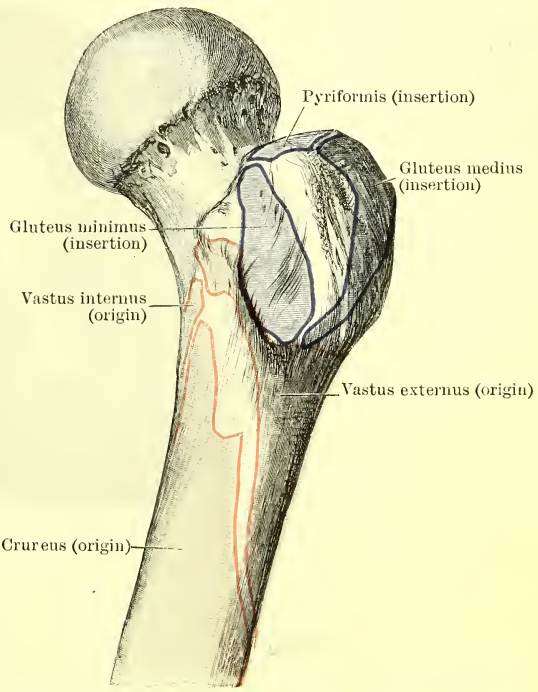


FIG. 277.—MUSCLE-ATTACHMENTS TO THE ANTERIOR SURFACE OF THE UPPER PART OF THE FEMUR.

It forms a thick, broad muscle directed downwards and forwards, and is **inserted** by a broad membranous tendon into (1) the outer border of the tendon of the rectus femoris, (2) the upper and outer border of the patella, and (3) the capsule of the knee-joint, and the external lateral ligament of the patella. The vastus externus is covered superficially by the fascia lata and the ilio-tibial band. A bursa intervenes between it and the membranous insertion of the gluteus maximus: at its inner border is the rectus femoris; and under cover of it, on a deeper plane, is the crureus, which is also to a large extent concealed by the muscle. Between the vastus externus and crureus is the descending branch of the external circumflex artery.

The **vastus internus** (m. vastus medialis) is larger than the vastus externus and has a more extensive **origin**, from (1) the shaft of the femur—from the lower two-thirds or more of the spiral line, the linea aspera, and the upper two-thirds of the line leading from the linea aspera to the internal condyle of the femur; (2) the membranous expansion of the fascia lata which lies beneath the sartorius and forms the roof of Hunter's canal; and (3) the internal intermuscular septum and the tendon of the adductor magnus (Figs. 277, p. 361, and 281, p. 365).

From its origin the muscle is directed downwards and outwards towards the knee; it is **inserted** by a strong aponeurotic tendon into (1) the inner border of the rectus tendon; (2) the upper and inner border of the patella; and (3) the capsule of the knee-joint and the internal lateral ligament of the patella. The vastus internus is superficial except at its origin, which is concealed by the sartorius muscle and femoral vessels. Along its outer side are the rectus and crureus; the muscle conceals the inner side of the shaft of the femur and the crureus, with which it is closely incorporated in its lower two-thirds.

The **crureus muscle** (m. vastus intermedius) **arises** by fleshy fibres (1) from the

upper two-thirds of the shaft of the femur on the anterior and external surfaces, (2) from the lower half of the outer lip of the linea aspera and the upper part of the line leading therefrom to the external condyle, as well as (3) from a corresponding portion of the external intermuscular septum (Fig. 277, p. 361).

For the most part deeply placed, the muscle is directed downwards to an **insertion** into the deep surface of the tendons of the rectus and vasti muscles by means of fibres which join a membranous expansion on its surface.

The crureus is concealed by the rectus and vasti muscles, and externally, in the lower half of the thigh, by the ilio-tibial band. It is closely adherent to the vastus externus muscle in the middle third of the thigh; it is inseparable from the vastus internus below the upper third. Beneath the crureus is the femur;

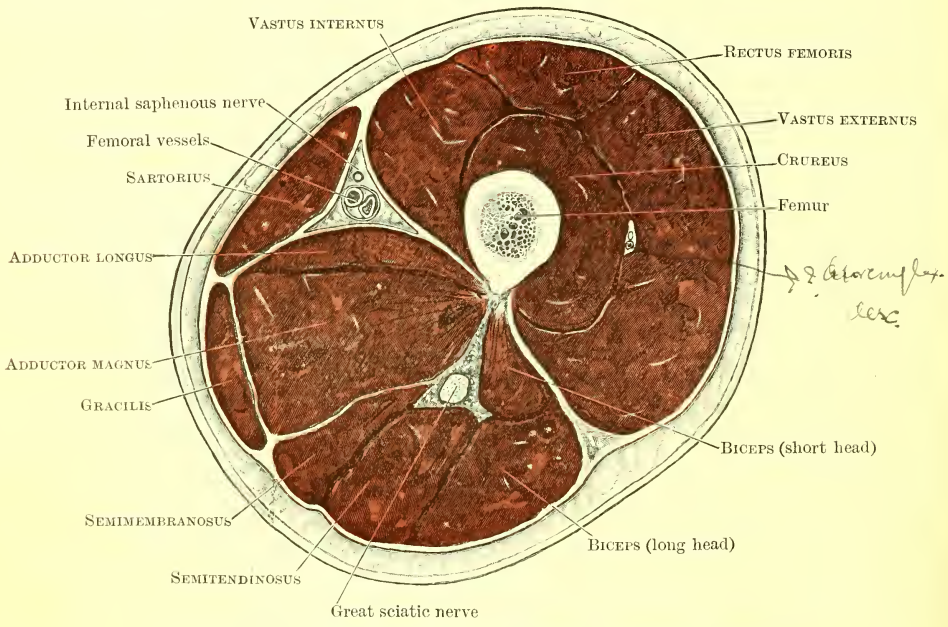


Fig. 278.—Transverse Section of the Thigh (Hunter's Canal).

and in the lower third of the thigh it conceals the subcrureus muscle, a bursa, and the upward prolongation of the synovial membrane of the knee-joint.

The **subcrureus** consists of a number of separate bundles of muscular fibres **arising** beneath the crureus from the lower fourth of the front of the femur, and **inserted** into the synovial membrane of the knee-joint beneath the tendon of the rectus femoris.

The four elements composing the quadriceps extensor muscle have been traced in their convergence to the patella and the lateral ligaments of the patella. Their ultimate **insertion** is into the tibia (Fig. 279, p. 363), by means of the **ligamentum patellæ** and the **lateral ligaments of the patella.** The patella, indeed, is in one sense a sesamoid bone formed in the tendon of the muscle, the ligamentum patellæ being the real tendon of insertion, and the lateral ligaments fascial expansions from its borders. The insertion of the muscle forms the front of the capsule of the knee-joint.

The **ilio-psoas muscle** is a compound muscle, consisting of one or sometimes two elements,—**psoas (magnus and parvus)**, connecting the femur and pelvic girdle to the axial skeleton; and another element, the **iliacus,** extending between the innominate bone and the femur. The muscles chiefly occupy the posterior wall of the abdomen and false pelvis, their insertions only appearing in the thigh below Poupart's ligament.

The **psoas magnus** (m. psoas major) is a large pyriform muscle, which has an extensive **origin** by fleshy fibres from the vertebral column in the lumbar region. It arises (1) from the intervertebral discs above each lumbar vertebra, and from the

adjacent margins of the vertebræ—from the lower border of the 12th thoracic to the upper border of the 5th lumbar vertebra; (2) it arises also from four aponeurotic arches which pass over the sides of the bodies of the first four lumbar vertebræ; and (3) it has an additional origin posteriorly from the transverse processes of all the lumbar vertebræ. The fibres form a fusiform muscle directed downwards over the pelvic brim and beneath Poupart's ligament, ending in a tendon which is **inserted** into the apex of the lesser trochanter of the femur (Fig. 281, p. 365).

The psoas muscle occupies the posterior abdominal wall, the false pelvis, and the thigh. In the abdomen it lies in the groove alongside the bodies of the lumbar vertebræ, in front of the transverse processes, and is enveloped by a fascia derived from the lumbar aponeurosis. The abdominal viscera in contact with it are: the kidney and colon on both sides, with the duodenum on the right, and the pancreas on the left side. The ureter is in front of it, along with the spermatic or ovarian, the renal and colic vessels. The inferior vena cava is in front of the right muscle; the inferior mesenteric vein is in front of that of the left side. The lumbar plexus is embedded in its substance, and the nerves of distribution emerge from its surface and borders. In the false pelvis the psoas covers the pelvic brim, and is covered by the ureter, the iliac vessels, the ileum on the right side, and the iliac colon on the left side. The vas deferens and spermatic vessels cross over it just above Poupart's ligament. In Scarpa's triangle the tendon is behind the femoral vessels, between the iliacus and pectineus, and in front of the obturator externus muscle and the hip-joint. A bursa, which may be continuous with the synovial cavity of the hip-joint, separates the tendon from the pubis and the capsule of the hip-joint.

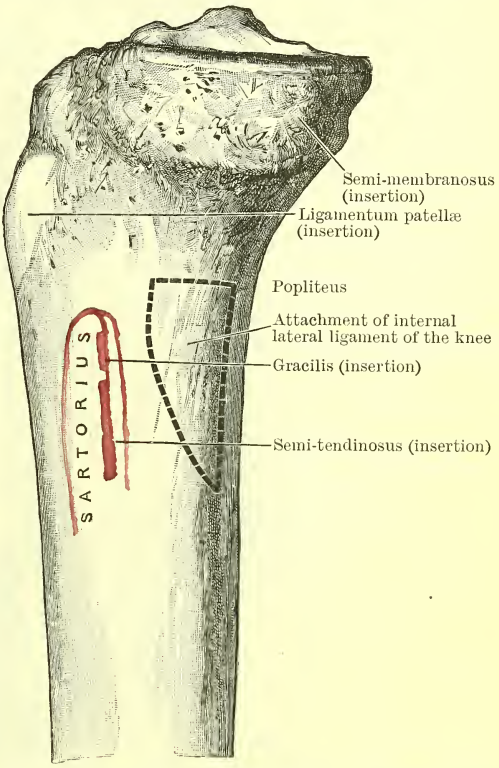


FIG. 279.—MUSCLE-ATTACHMENTS TO THE INNER SIDE OF THE UPPER PART OF THE TIBIA.

The **psoas parvus** (m. psoas minor) is often absent (40 per cent). It **arises** by fleshy fibres from the intervertebral disc between the last thoracic and first lumbar vertebræ, and from the contiguous margins of these vertebræ. The muscle is closely apposed to the anterior surface of the psoas magnus. It forms a slender fleshy belly, and is **inserted** by a narrow tendon into the middle of the ilio-pectineal line and the ilio-pectineal eminence, its margins blending with the fascia covering the psoas magnus.

The **iliacus muscle arises** by fleshy fibres, mainly from a horseshoe-shaped origin around the margin of the iliac fossa; it has additional origins also from the ala of the sacrum, the anterior sacro-iliac, lumbo-sacral, and ilio-lumbar ligaments, and outside the pelvis, from the upper part of the ilio-femoral band. It is a fan-shaped muscle, its fibres passing downwards over the hip-joint towards the small trochanter of the femur. It is **inserted** by fleshy fibres (1) into the outer side of the tendon of the psoas magnus; (2) into the concave anterior and upper surfaces of the small trochanter; and (3) into the shaft of the femur below the small trochanter for about an inch (Fig. 281, p. 365); and (4) by its most external fibres into the capsule of the hip-joint. These fibres are often separate, forming the **iliacus minor**, or **ilio-capsularis.**

The muscle occupies the false pelvis and Scarpa's triangle. It forms the back

wall of the false pelvis and is covered anteriorly by the iliac fascia. It is in contact with the cæcum on the right side and the iliac colon on the left side. The psoas muscle lies along its inner border, with the anterior crural nerve in the interval between them. After passing beneath Poupart's ligament, and over the capsule of the hip-joint, the muscle occupies the outer part of the floor of Scarpa's triangle, internal to the sartorius and rectus femoris muscles.

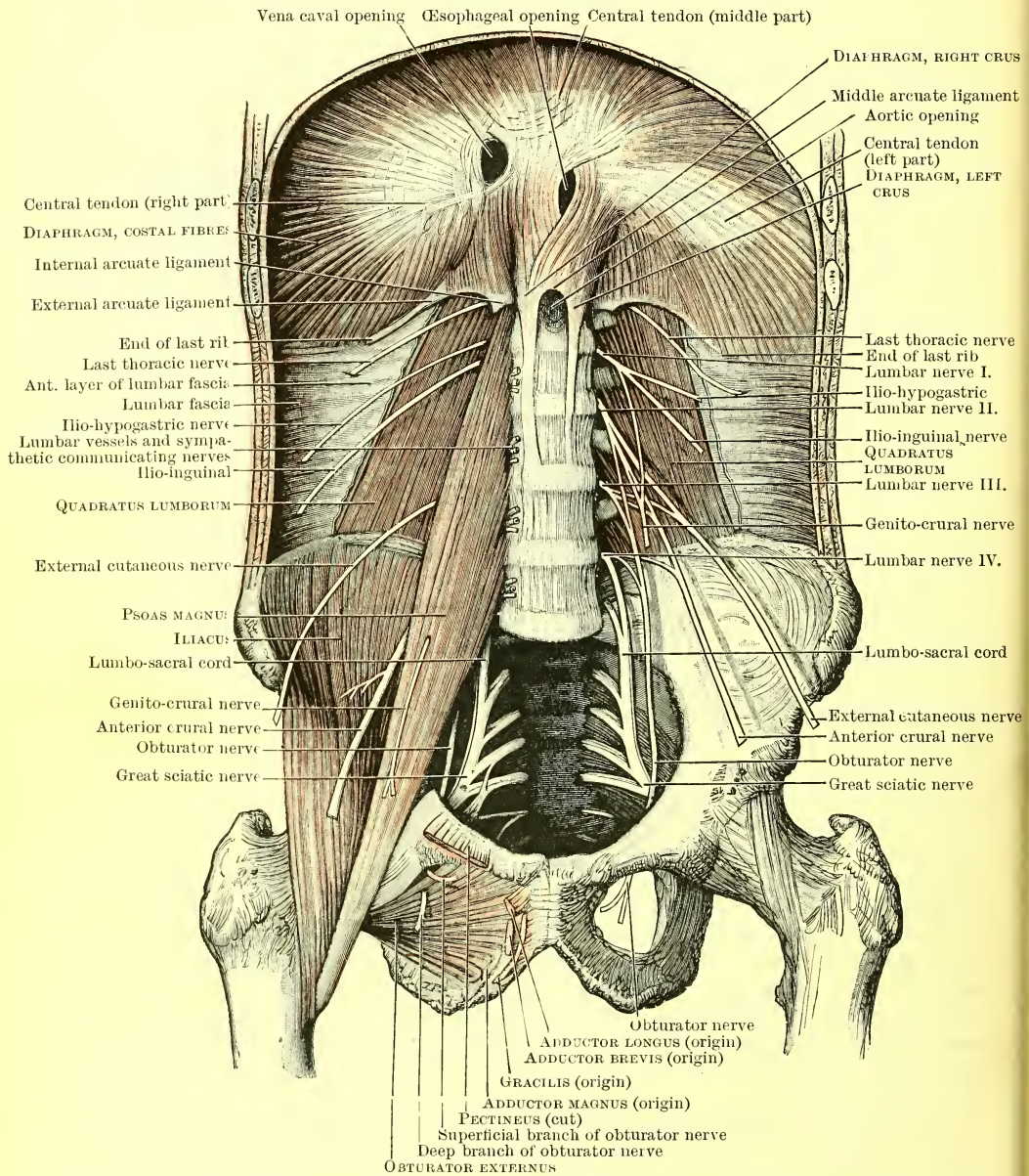


Fig. 280.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

The **pectineus** muscle **arises** by fleshy fibres from the sharp anterior portion of the ilio-pectineal line of the pubis, and from the triangular surface of the pubic bone in front of this (Fig. 282, p. 366). It also arises from the femoral surface of Gimbernat's ligament, and from the pubic portion of the fascia lata which covers it. Forming a broad muscular band, it is directed obliquely downwards, backwards, and outwards, to be **inserted** by a thin flat tendon about two inches in length into the upper half of the pectineal line leading from the back of the

small trochanter of the femur towards the linea aspera; its lower attachment being placed in front of the insertion of the adductor brevis muscle (Fig. 281, p. 365).

The pectineus forms a part of the floor of Scarpa's triangle. Covered by the pubic portion of the fascia lata, it is partially concealed by the femoral vessels and the insertion of the ilio-psoas. It lies in front of the pubic bone, the obturator externus and adductor brevis muscles, and the superficial part of the obturator nerve. Its outer border is separated from the psoas by the internal circumflex vessels. Its inner border is in contact above with the adductor longus, but is separated from it below by the deep femoral vessels. The muscle may be occasionally divided into inner and outer parts, the former innervated by the obturator, the latter by the anterior crural nerve.

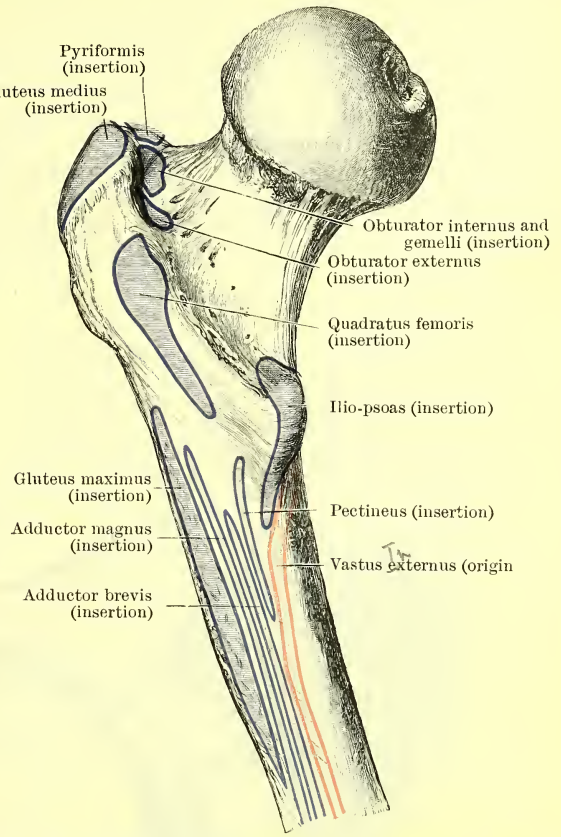


FIG. 281.—MUSCLE-ATTACHMENTS TO THE POSTERIOR ASPECT OF THE UPPER PART OF THE FEMUR.

THE MUSCLES ON THE INNER SIDE OF THE THIGH.

The muscles on the inner side of the thigh include the adductors of the femur—the adductor longus, adductor brevis, and adductor magnus; the gracilis, and the obturator externus.

The **gracilis muscle** is a long flat band placed on the inner side of the thigh and knee. It **arises** by a thin aponeurotic tendon from the lower half of the edge of the symphysis pubis, and for a similar distance from the border of the adjoining part of the pubic arch (Fig. 282, p. 366). Its flattened fleshy belly passes down on the inner side of the thigh to the knee, where it ends in a tendon, which expands to be **inserted** into the inner side of the shaft of the tibia just below the inner tuberosity, behind the sartorius and above and in front of the semitendinosus (Fig. 279, p. 363). It is separated from the sartorius tendon by a bursa, and beneath its tendon is another bursa common to it and the semitendinosus.

The gracilis is superficial in its whole extent, except at its insertion which is concealed by the insertion of the sartorius muscle. Its deep surface covers the borders of the adductor longus and adductor magnus muscles, as well as the superficial part of the obturator nerve. At the inner side of the knee it lies between the sartorius and semitendinosus.

The **adductor longus** is a triangular muscle **arising** by a rounded tendon from the anterior surface of the body of the pubis in the angle between the crest and symphysis (Fig. 282, p. 366). Extending downwards and outwards, it is **inserted** into the middle two-fourths of the inner lip of the linea aspera in front of the adductor magnus. Lying in the same plane as the pectineus, the adductor longus is in contact with that muscle near its origin, but is separated from it below by an interval through which the deep femoral vessels pass. Its inner border is in contact with the gracilis and sartorius muscles. Its anterior surface forms part of the floor of Scarpa's triangle above, part of the floor of Hunter's canal below. It is covered near its insertion by the sartorius and the femoral vessels, and it is connected to

the origin of the vastus internus by an aponeurotic expansion of fascia beneath the sartorius, forming the roof of Hunter's canal. Its posterior surface is in relation with the adductor brevis and the adductor magnus muscles, the deep femoral vessels, and the superficial part of the obturator nerve. The adductor longus may be double, or more or less fused with the pectineus.

The **adductor brevis** is a large muscle which **arises** by fleshy and short tendinous fibres from an elongated oval surface on the front of the body and upper part of the descending ramus of the pubis, surrounded by the other muscles of this group (Fig. 282, p. 366). Directed downwards and outwards, the muscle expands, to be **inserted** by a short aponeurotic tendon, behind the insertion of the pectineus, into the lower two-thirds of the line leading from the small trochanter of

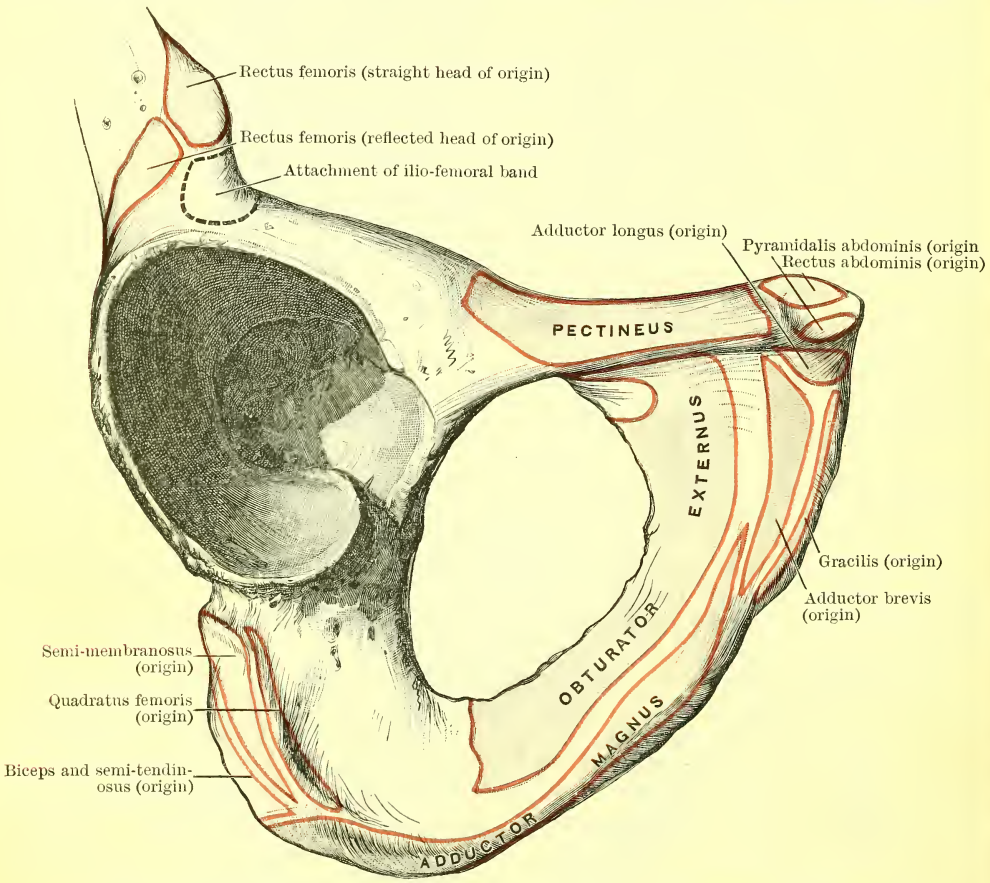


FIG. 282.—MUSCLE-ATTACHMENTS TO THE OUTER SURFACE OF THE PUBIS AND ISCHIUM.

the femur to the linea aspera, and to the upper fourth of the linea aspera itself (Fig. 286, p. 370).

The adductor brevis is the central muscle of the adductor group. It is almost wholly concealed by the pectineus and adductor longus. It rests upon the adductor magnus; at its upper border is the obturator externus, separated from it by the internal circumflex vessels; at its lower border is the adductor longus, separated by the deep femoral vessels. It separates the superficial and deep parts of the obturator nerve in their course down the thigh.

The **adductor magnus**, the largest of the adductor group, is a roughly triangular muscle **arising** mainly by fleshy fibres by a curved origin from the lower part of the outer border and a large portion of the adjoining inferior surface of the ischial tuberosity, from the edge of the ischial ramus, and from the anterior surface of the descending ramus of the pubis, its most anterior fibres arising between the obturator externus and adductor brevis (Figs. 282, p. 366, and 285, p. 369).

Its upper fibres are directed horizontally outwards from the pubis towards the upper part of the femur; the lowest fibres are directed downwards from the ischial tuberosity to the internal condyle of the femur; while the intermediate fibres radiate obliquely outwards and downwards. The muscle is **inserted** by tendinous fibres (1) into the space below the insertion of the quadratus femoris, above the linea aspera; (2) into the whole length of the linea aspera; (3) into the internal supracondyloid ridge of the femur; (4) into the adductor tubercle on the internal condyle of the femur; and (5) into the internal intermuscular septum (Fig. 286, p. 370). The part of the muscle attached to the space above the linea aspera is often separated from the rest as the **adductor minimus**. The attachment of the muscle into the supracondyloid ridge is interrupted for the passage of the

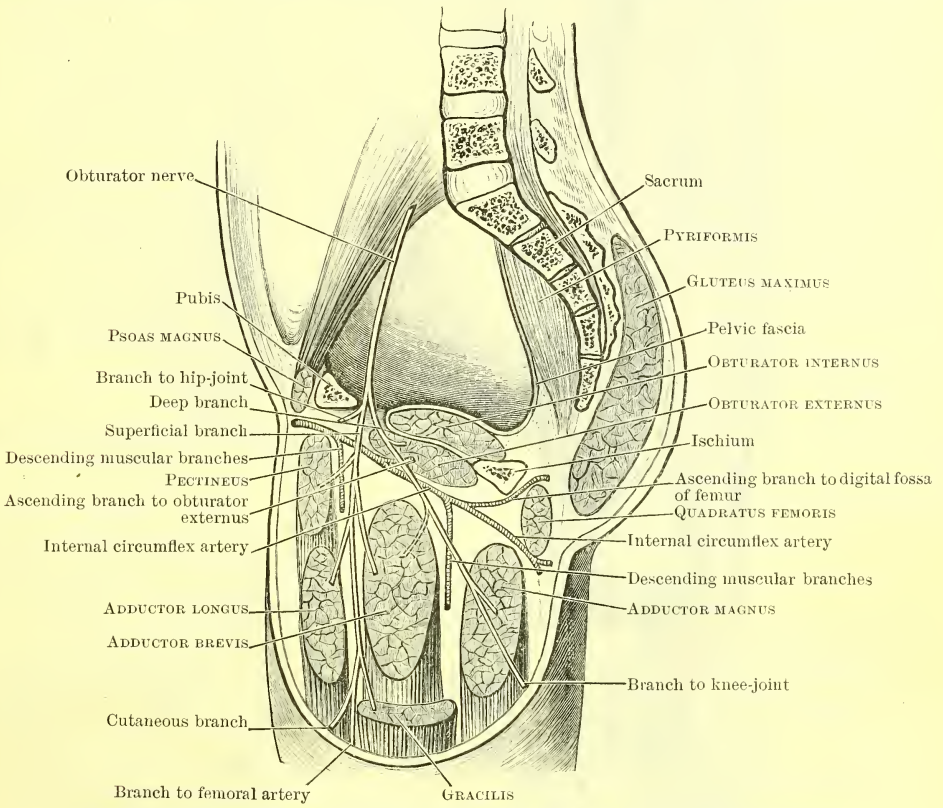


Fig. 283.—Scheme of the Course and Distribution of the Obturator Nerve.

femoral vessels to the popliteal space. The attachment to the internal condyle is by means of a strong tendon which receives the fibres arising from the ischium (the part of the muscle associated with the hamstring group). This tendon is closely connected with the internal lateral ligament of the knee-joint.

The adductor magnus intervenes between the other adductor muscles in front and the hamstring muscles behind. It is concealed anteriorly by the pectineus, adductor brevis, adductor longus, and sartorius. The deep femoral artery lies on it above. It forms the floor of Hunter's canal below, where the femoral vessels lie upon it. The hamstring muscles and great sciatic nerve are behind the adductor magnus; the obturator externus and quadratus femoris are at its upper border; and along its inner border are the gracilis and sartorius muscles.

The **obturator externus** is placed deeply under cover of the previous muscles. It is a fan-shaped muscle lying horizontally in the angle between the hip bone and the neck of the femur. It **arises** from the outer surface of the pubis and ischium, which form the inferior half of the margin of the thyroid foramen, and from the corresponding portion of the outer surface of the obturator membrane (Figs. 282, p. 366, and 285, p. 369). Its fibres converge towards the great trochanter, and

end in a stout tendon which, after passing below and behind the hip-joint, is **inserted** into the digital fossa of the great trochanter (Figs. 286, p. 370, and 289, p. 371). The inferior surface of the muscle is in contact with the pectineus, adductor brevis, and adductor magnus muscles, separated from them by the internal circumflex vessels. The superior surface is in relation to the obturator membrane and the neck of the femur. The tendon lies below and behind the capsule of the hip-joint, and near its insertion appears in the buttock (under cover of the gluteus maximus) between the inferior gemellus and quadratus femoris muscles.

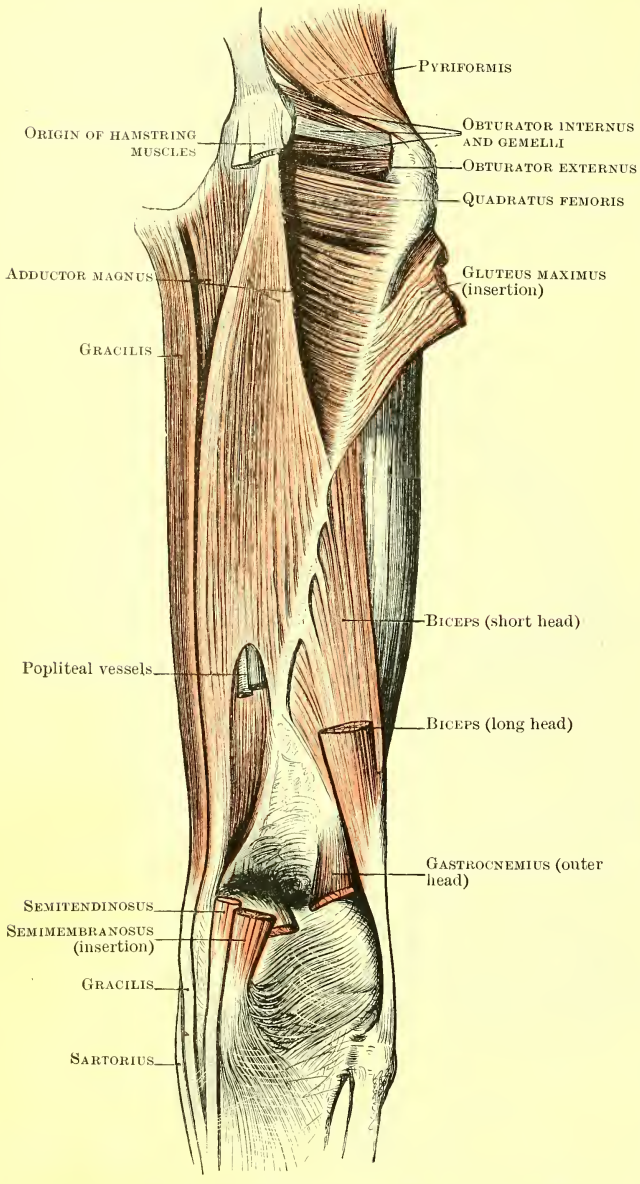


Fig. 284.—The Posterior Surface of the Thigh (superficial muscles removed).

THE MUSCLES OF THE BUTTOCK.

This group includes the three glutei muscles, the tensor fasciæ femoris, pyriformis, obturator internus and gemelli, and quadratus femoris.

The **gluteus maximus** is a large quadrilateral muscle, with a crescentic **origin**, from (1) a portion of the area on the dorsum ilii above the superior curved line (Fig. 285, p. 369); (2) the tendon of the erector spinæ; (3) the posterior surface of the sacrum and coccyx (Fig. 311, p. 396); and (4) the posterior surface of the great sacro-sciatic ligament. The fibres which form its upper and outer border take origin directly from the fascia lata which envelopes the muscle. The muscle forms a large fleshy mass, whose fibres are directed obliquely outwards over the buttock, invested by the fascia lata, and are **inserted** by short tendinous fibres, partly into the fascia lata over the great trochanter of the femur (joining the ilio-tibial band), and partly into the gluteal ridge (Fig. 286, p. 370). The fascia lata receives the insertion of the whole of the superficial fibres of the muscle and the upper half of the deep fibres. The lower half of the deep portion of the muscle is inserted for the most part into the gluteal ridge; but the lowest fibres of all are inserted into fascia lata, and are thereby connected with the external intermuscular septum and the origin of the short head of the biceps.

The gluteus maximus is the coarsest and heaviest muscle in the body. By its

weight it helps to form the fold of the nates. It is superficial in its whole extent. The gluteus medius is visible at its upper border, covered by the fascia lata; at its lower border the hamstring muscles and great sciatic nerve appear on their way down the thigh. The muscle conceals the bones from which it arises, along with the great sciatic ligament, the ischial tuberosity, and the great trochanter of the femur. It also conceals the gluteus medius and pyriformis, with a branch of the gluteal artery between them; the obturator internus and gemelli, with the sciatic vessels and nerves, the pudic vessels and nerve, and the muscular branches of the sacral plexus above them, and the obturator externus and a branch of the internal circumflex artery below them; the quadratus femoris and upper part of the adductor magnus muscles, with the internal circumflex vessels between them. It covers the origins of the hamstring muscles, and by its insertion into the fascia lata,

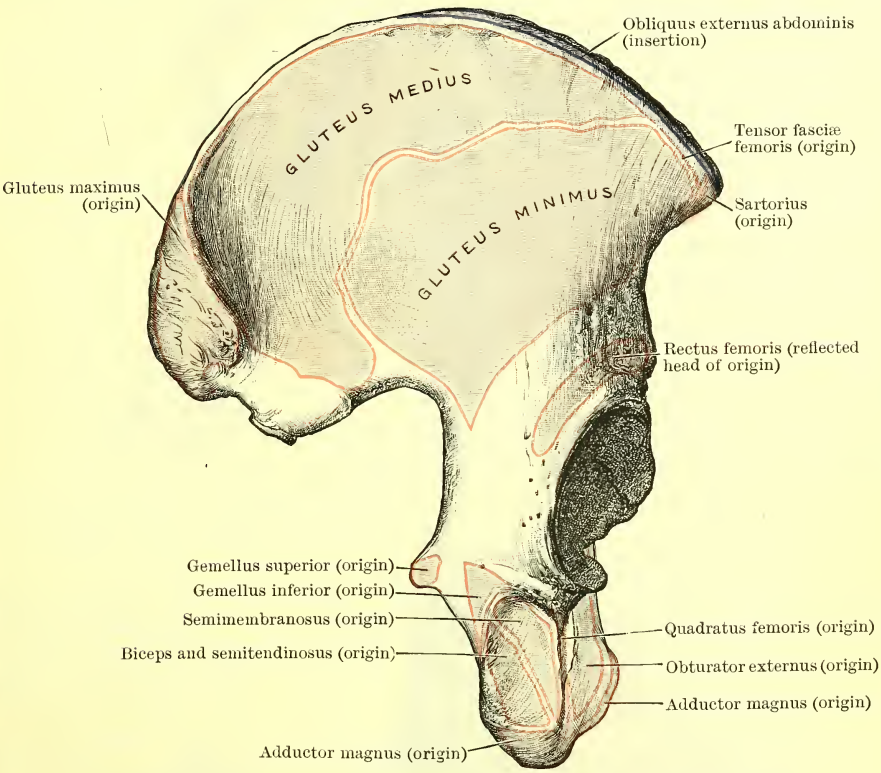


FIG. 285.—MUSCLE-ATTACHMENTS TO THE DORSUM ILII AND TUBER ISCHII.

the vastus externus. The first perforating artery pierces the attachment of the muscle to the gluteal ridge. Three bursæ are beneath it: one (not always present) over the tuberosity of the ischium, a second over the outer side of the great trochanter, and a third over the vastus externus. The fibres of the gluteus maximus arising from the coccyx may form a separate muscle (**agitator caudæ**).

The **tensor fasciæ femoris** (m. tensor fasciæ latæ), lying on the same plane as the gluteus maximus, **arises** from the iliac crest and the dorsum ilii just external to the anterior superior spine, and from the fascia covering its outer surface (Fig. 285, p. 369). Invested like the gluteus maximus by the fascia lata, it is **inserted** about the level of the great trochanter of the femur into the fascia, which forms the **ilio-tibial band** (p. 357).

The tensor fasciæ femoris muscle is superficially placed, and is enclosed in a strong investment of the fascia lata, the deeper layer of which is prolonged up to join the tendon of the rectus femoris and the capsule of the hip-joint. The muscle is placed along the anterior borders of the gluteus medius and gluteus minimus, and conceals branches of the gluteal and external circumflex vessels and the termination of the superior gluteal nerve. The sartorius muscle is adjacent to it anteriorly at

its origin, and is separated from it below by the rectus femoris.

The **gluteus medius** arises by fleshy and tendinous fibres (1) from the dorsum ilii, between the iliac crest and the superior curved line above and the middle curved line below (Fig. 285, p. 369), and (2) from the strong fascia lata covering its surface anteriorly. It is a fan-shaped muscle, its fibres converging to the great trochanter, to be **inserted** by a strong, short tendon into the postero-superior angle of the trochanter, and into a well-marked diagonal line on its outer surface (Figs. 286, p. 370, 277, p. 361, and 289, p. 371).

The muscle is covered along its anterior border by the tensor fasciæ femoris. Its surface is covered over by the fascia lata and the gluteus maximus. Its inferior border is separated from the pyriformis muscle by the superficial branch of the gluteal artery. Its deep surface is in contact with the gluteus minimus, the gluteal vessels, the superior gluteal nerve, and the insertion of the pyriformis muscle. A bursa is placed beneath the tendon at its insertion.

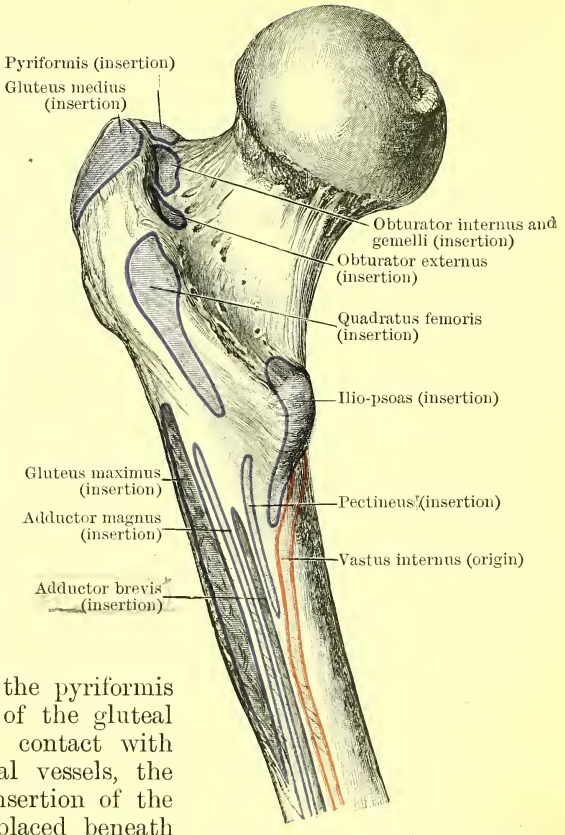


FIG. 286.—MUSCLE-ATTACHMENTS TO THE POSTERIOR ASPECT OF THE UPPER PART OF THE FEMUR.

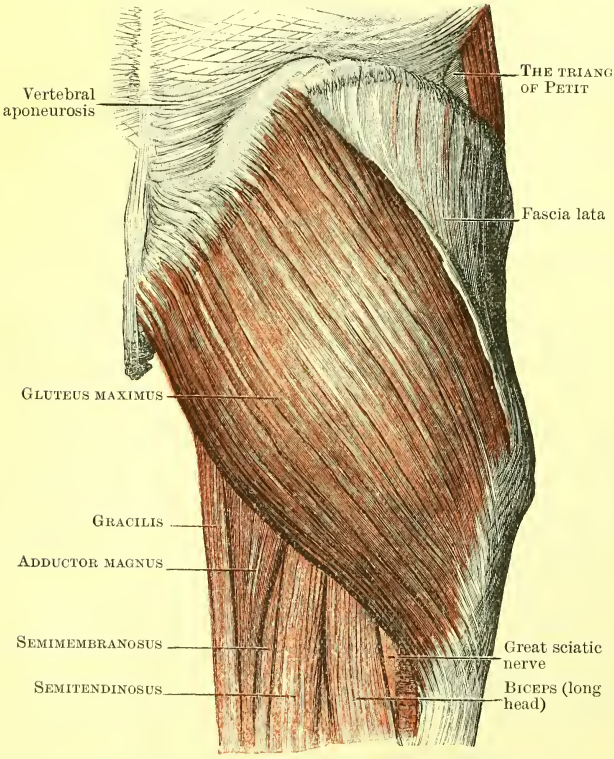


FIG. 287.—THE GLUTEUS MAXIMUS MUSCLE.

The **gluteus minimus** arises by fleshy fibres from the dorsum ilii between the middle and inferior curved lines (Fig. 285, p. 369). This muscle is fan-shaped and its fibres converge to the antero-superior angle of the great trochanter, to be **inserted** into the anterior surface of the trochanter, and sometimes also into the front part of the upper border (Figs. 277, p. 361, and 289, p. 371). It is also inserted into the capsule of the hip-joint. The muscle is concealed by the tensor fasciæ femoris and gluteus medius. The pyriformis is in contact with its inferior border, and beneath it are the capsule of the

hip-joint and the reflected tendon of the rectus femoris muscle. A bursa is placed beneath the tendon in front of the great trochanter.

The **pyriformis** is one of the few muscles connecting the lower limb to the axial skeleton. It **arises** (1) within the pelvis from the pedicles of the second, third, and fourth sacral vertebræ, and from the adjacent part of the bone external to the anterior sacral foramina; passing outwards through the great sacro-sciatic foramen, it receives an origin (2) from the upper margin of the great sciatic notch of the ilium, and (3) from the pelvic surface of the great sacro-sciatic ligament. In the buttock it forms a rounded tendon, which is **inserted** into a facet on the upper border and inner aspect of the great trochanter of the femur, partly surrounding the insertion of the obturator internus (Figs. 286, p. 370, 277, p. 361, and 289, p. 371).

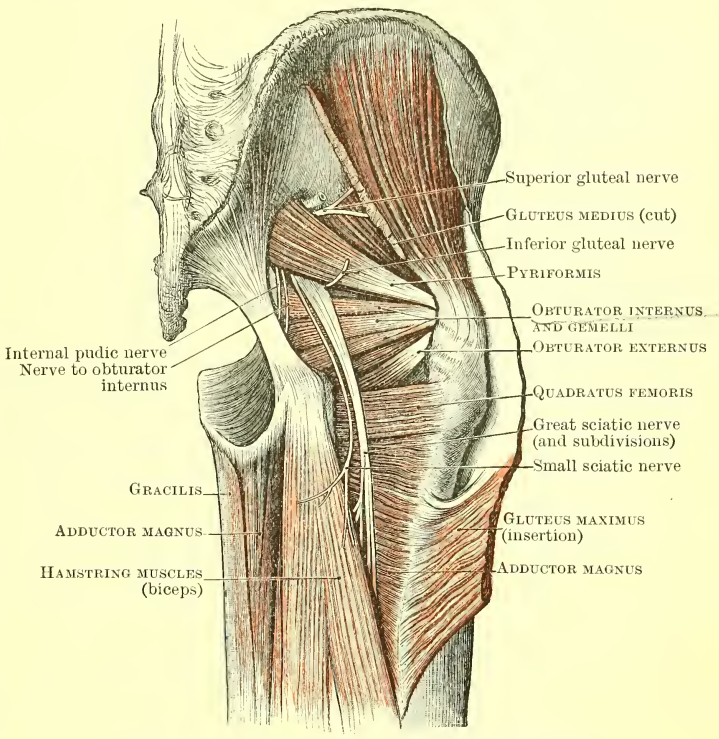


Fig. 288.—The Muscles and Nerves of the Buttock.

The gluteus maximus is reflected; and the gluteus medius is cut in part to show the gluteus minimus.

The pyriformis, besides appearing in the buttock, lines the posterior wall of the pelvis. In the pelvis it lies behind the rectum, covered by a thin layer of the parietal pelvic fascia. In the buttock it is covered by the gluteus maximus, and at its insertion by the gluteus medius, and it lies upon the ilium and the capsule of the hip-joint. At its upper border are the gluteus medius and gluteus minimus, separated by the superior gluteal nerve and the gluteal artery; its lower border is separated from the gemelli and obturator internus by an interval in which the sciatic and pudic vessels and the nerves of the sacral plexus appear. The anterior fibres of the muscle may be separate.

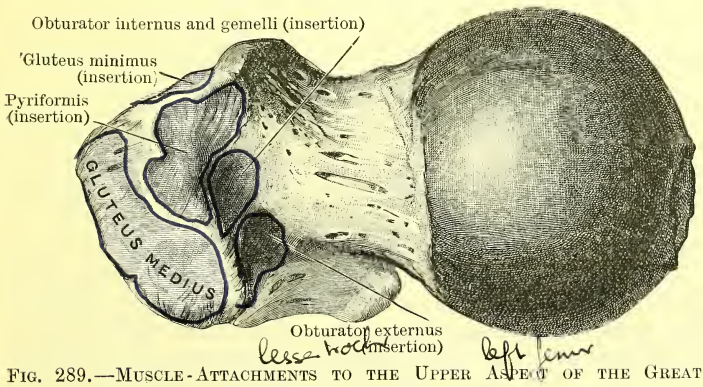


Fig. 289.—Muscle-Attachments to the Upper Aspect of the Great Trochanter of the Femur.

The **obturator internus arises** by fleshy fibres on the pelvic aspect of the hip bone, (1) from the whole of the margin of the thyroid foramen (except the obturator notch, and a portion posteriorly opposite the small sciatic notch); (2) from the surface of the obturator membrane; (3) from the whole of the pelvic surface of

the hip bone behind and above the thyroid foramen; and (4) slightly from the parietal pelvic fascia covering it internally. It is a fan-shaped muscle, and its fibres converging to the lesser sacro-sciatic foramen, give rise to several tendons which hook round the margin of the foramen (a bursa intervening), and after traversing the buttock, unite together to be **inserted** into a facet on the inner surface of the great trochanter of the femur above the digital fossa (Figs. 286, p. 370, and 289, p. 371).

In the pelvis the muscle occupies the lateral wall, covered by the parietal (obturator) layer of pelvic fascia, which separates it from the pelvic cavity above and the ischio-rectal fossa below. It is separated from the contents of the pelvis, above by the peritoneum and extra-peritoneal fat, below by the fat in the ischio-rectal fossa. The internal pudic vessels and nerve cross it in the outer wall of the fossa in a special sheath of the fascia. In the buttock the tendon is embraced by the gemelli muscles which are attached to its upper and lower margins. The tendon is crossed by the sciatic vessels and nerves, and lies against the upper and back part of the capsule of the hip-joint.

The **gemelli muscles** form accessory portions of the obturator internus. They are two in number, **superior** and **inferior**, and are wholly composed of fleshy fibres.

The **superior gemellus arises** from the gluteal surface of the ischial spine and from the upper part of the margin of the lesser sciatic notch (Fig. 285, p. 369). It is **inserted** into the upper margin and superficial surface of the tendon of the obturator internus muscle.

The **gemellus inferior arises** from the upper part of the gluteal surface of the ischial tuberosity and the lower part of the margin of the lesser sciatic notch (Fig. 285, p. 369). It is **inserted** into the lower margin and superficial aspect of the tendon of the obturator internus.

The **quadratus femoris arises** from the outer margin of the ischial tuberosity (Figs. 282, p. 366, and 285, p. 369), and is **inserted** into the quadrate tubercle and quadrate line of the femur (Fig. 286, p. 370). The muscle is placed beneath the gluteus maximus, and is crossed by the sciatic vessels and nerves. Its origin is concealed by the hamstring muscles. Its deep surface is in contact with the obturator externus muscle and the small trochanter of the femur, a bursa intervening. Its upper border is separated from the inferior gemellus by an interval, containing the tendon of the obturator externus and the ascending branch of the internal circumflex artery. Its lower border is separated from the upper margin of the adductor magnus by the internal circumflex vessels. The muscle is not infrequently fused with the adductor magnus.

THE MUSCLES ON THE BACK OF THE THIGH.

The Hamstring Muscles.

The muscles comprised in this series include the biceps, semitendinosus and semimembranosus. A part of the adductor magnus, already described, also belongs morphologically to this group.

The **biceps flexor cruris** (m. biceps femoris) has a double **origin**. (1) *Its long head* arises by means of a tendon, in common with the semitendinosus, from the lower and inner facet upon the tuberosity of the ischium (Figs. 282, p. 366, and 285, p. 369) and from the great sacro-sciatic ligament. This head, united for a distance of two to three inches with the semitendinosus, forms a separate fleshy mass, which extends to the lower third of the thigh, to end in a tendon joined by the short head of the muscle. (2) *The short head* arises separately by fleshy and tendinous fibres (1) from the whole length of the outer lip of the linea aspera and the upper two-thirds of the external supra-condyloid ridge of the femur, and (2) from the external intermuscular septum for a corresponding extent. The upper limit of its origin is sometimes blended with the insertion of the lowest fibres of the gluteus maximus. The fibres of the short head, directed downwards, join the tendon of the long head, and the muscle is **inserted** (1) into the head of the

fibula by a strong tendon, which is split into two parts by the long external lateral ligament of the knee-joint; (2) by a slip attached to the outer tuberosity of the tibia; and (3) along its posterior border by a fascial expansion which connects the tendon with the popliteal fascia.

The long head of the biceps is concealed at its origin by the gluteus maximus muscle. In the lower two-thirds of the thigh it is superficially placed, with the semitendinosus and semimembranosus on its inner side. It conceals the great sciatic nerve, the origins of the semimembranosus and quadratus femoris, the adductor magnus, and the short head of the muscle. The united heads assist in

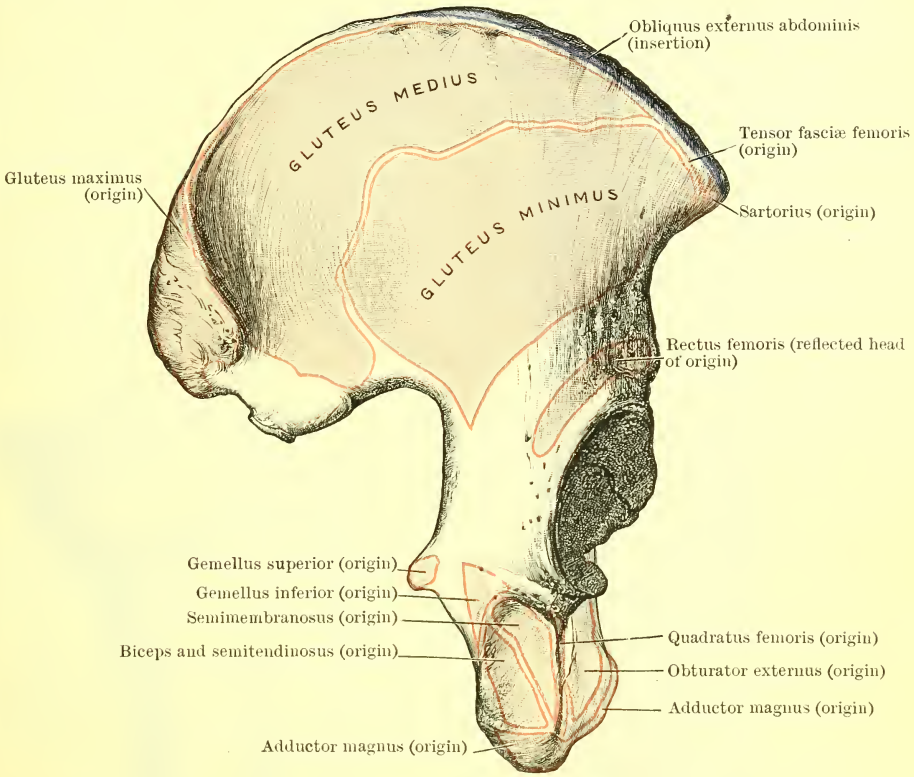


FIG. 290.—MUSCLE-ATTACHMENTS TO THE DORSUM ILII AND TUBER ISCHII.

forming the outer boundary of the popliteal space, and partially conceal the outer head of the gastrocnemius.

The short head may be absent: there may be an additional origin from the ischium or femur; and the long head may send a slip to the gastrocnemius or tendo Achillis (**tensor fasciæ suralis**).

The **semitendinosus arises**, in common with the long head of the biceps, from the lower and inner facet upon the ischial tuberosity (Fig. 285, p. 369). Separating from the common tendon after a course of two or three inches, the muscle forms a long, narrow band which becomes tendinous in the middle third of the thigh. Passing over the inner side of the knee it spreads out and becomes membranous, and is **inserted** (1) into the inner side of the shaft of the tibia just below the internal tuberosity, below the gracilis and behind the sartorius (Fig. 292, p. 374), and (2) into the fascia lata of the leg. A bursa separates it from the sartorius in front, and another, common to it and the gracilis, lies beneath its insertion.

The origin of the muscle is concealed by the gluteus maximus. In the back of the thigh it is superficial to the semimembranosus; and at the inner side of the knee the tendon lies behind that of the gracilis, and also behind the sartorius. It forms one of the inner boundaries of the popliteal space. The belly of the muscle is marked by an oblique septal tendinous intersection about its middle.

The **semimembranosus** arises by a tendon from the upper and outer facet on the ischial tuberosity (Figs. 282, p. 366, and 285, p. 369). In the upper third of the thigh the tendon gives place to a rounded fleshy belly, which, becoming tendinous at the back of the knee, is **inserted** mainly into the horizontal groove on the back of the inner tuberosity of the tibia, and into a triangular area below the hinder end of the groove, and above the insertion of the popliteus (Figs. 292, p. 374, and 299, p. 383). A bursa lies beneath the tendon at its insertion. It has three *additional membranous insertions*: (1) a fascial band extends downwards and inwards to join the posterior border of the internal lateral ligament of the knee-joint; (2) another fascial band extends downwards and outwards, forms the fascia covering the popliteus

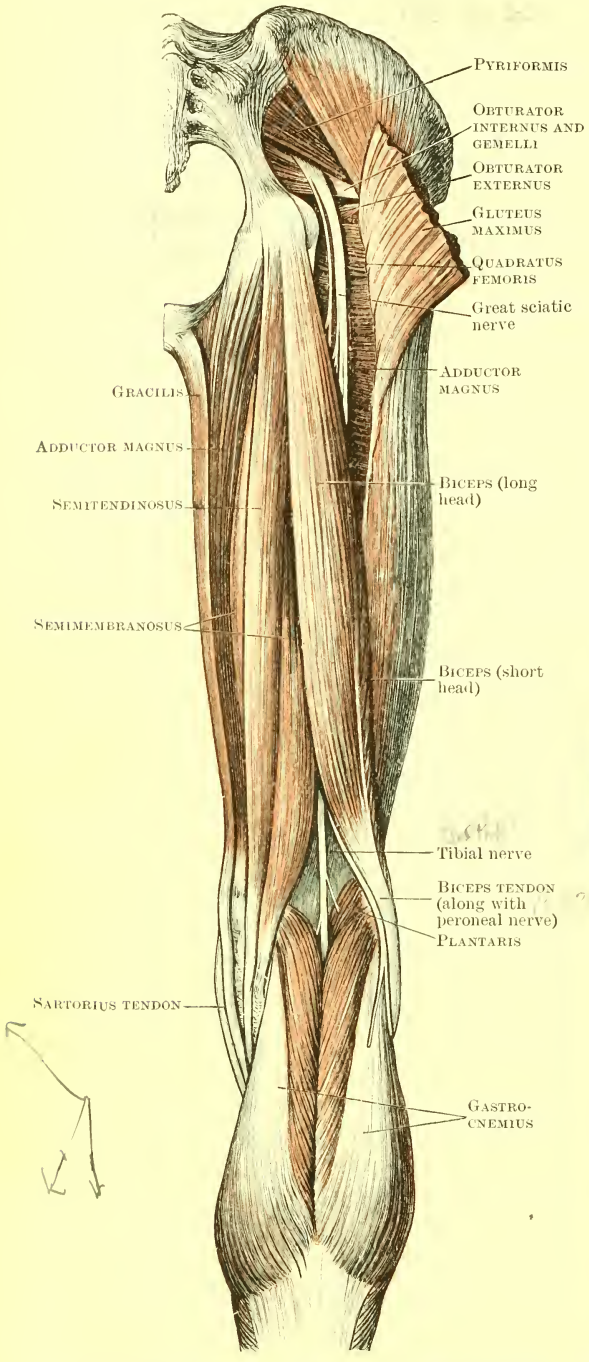


Fig. 291.—The Muscles on the Back of the Thigh.

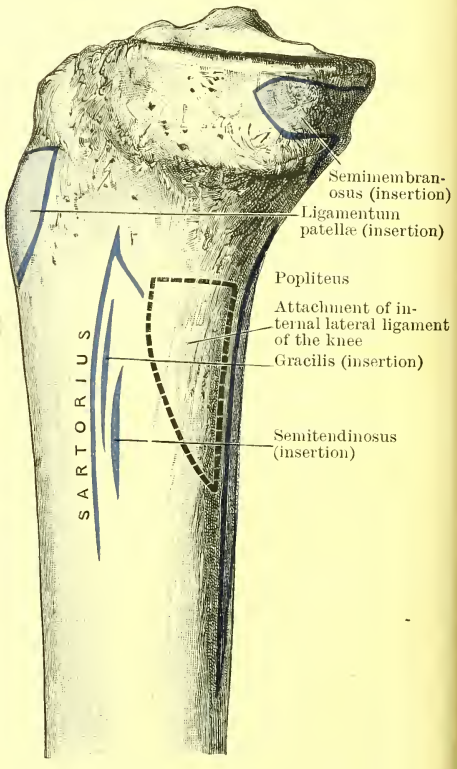


Fig. 292.—Muscle-Attachments to the Inner Side of the Upper Part of the Tibia.

muscle (popliteus fascia), and is attached to the oblique line of the tibia; and (3) a third strong band extends upwards and outwards to the back of the external condyle of the femur, forming the posterior ligament of the knee-joint.

The tendon of origin of the semimembranosus is concealed by the gluteus maximus, and immediately beyond the ischium it is grooved by the common origin of the long head of the biceps and semitendinosus. In the back of the thigh it is

covered by the semitendinosus, and lies upon the adductor magnus and great sciatic nerve. It forms part of the inner boundary of the popliteal space, and conceals the popliteal vessels. Its tendon passes over the inner head of the gastrocnemius on its way to its insertion.

Nerve-Supply of the Muscles of the Thigh and Buttock.

The innervation of the muscles described above is given in the following table:—

Muscles.	Nerves.	Origin.
Pectineus	Anterior crural	L. 2. 3.
Sartorius	Anterior crural	L. 2. 3.
Iliacus	Anterior crural	L. 2. 3. 4.
Psoas	Anterior crural	L. 2. 3. 4.
Quadriceps extensor	Anterior crural	L. 3. 4.
Vastus externus	Anterior crural	L. 3. 4.
Rectus femoris	Anterior crural	L. 3. 4.
Crureus	Anterior crural	L. 3. 4.
Vastus internus	Anterior crural	L. 3. 4.
Tensor fasciæ femoris	Superior gluteal	L. 4. 5. S. 1.
Gluteus minimus	Superior gluteal	L. 4. 5. S. 1.
Gluteus medius	Superior gluteal	L. 4. 5. S. 1.
Gluteus maximus	Inferior gluteal	L. 5. S. 1. 2.
Biceps (short head)	Peroneal (Ext. Popliteal)	L. 5. S. 1. 2.
Pyriformis	Sacral plexus	S. 1. 2.
Adductor longus	Obturator	L. 2. 3.
Gracilis	Obturator	L. 2. 3. 4.
Adductor brevis	Obturator	L. 3. 4.
Obturator externus	Obturator	L. 3. 4.
Adductor magnus	Obturator	L. 3. 4.
	Nerve to hamstrings (Sciatic)	L. 4. 5. S. 1.
Semimembranosus (Int. Popliteal)	Nerve to hamstrings	L. 4. 5. S. 1.
Semitendinosus (Int. Pop.)	Nerve to hamstrings	L. 5. S. 1. 2.
Biceps (long head)	Nerve to hamstrings	S. 1. 2. 3.
Quadratus femoris and inferior gemellus	Sacral plexus	L. 4. 5. S. 1.
Superior gemellus and obturator internus	Sacral plexus	S. 1. 2. 3.

Action of the Muscles of the Thigh and Buttock.

Most of the above muscles act on the pelvis and on the hip- and knee-joints. The psoas muscle in addition assists in the movements of the vertebral column (p. 398).

1. **Movements at the Hip-Joint.**—The movements of the thigh at the hip-joint are flexion and extension, adduction and abduction, internal and external rotation. The following table gives the muscles producing these movements:—

a. **Flexion** and **Extension.**	
Sartorius	Gluteus maximus
Iliacus	„ medius
Psoas	„ minimus
Rectus femoris	Biceps
Pectineus	Semitendinosus
Adductor longus	Semimembranosus
Gracilis	Adductor magnus
Obturator externus	

b. Adduction	and	Abduction.
Pectineus		Tensor fasciæ femoris
Adductor longus		Gluteus medius
„ brevis		Gluteus minimus
„ magnus		Obturator externus
Gracilis		Pyriformis)
Quadratus femoris		Obturator internus) during
Gluteus maximus		Gemelli) during flexion
(lower fibres)		Sartorius) flexion
		Gluteus maximus
		(upper fibres))

c. Internal Rotation	and	External Rotation.
Tensor fasciæ femoris		Obturator externus
Gluteus medius (anterior fibres)		Gluteus maximus (lower fibres)
„ minimus „ „		Quadratus femoris
		Gluteus medius) (posterior
		„ minimus) fibres)
		Pyriformis) during
		Obturator internus) during
		Gemelli) extension
		Sartorius
		Ilio-psoas
		Pectineus
		Adductor longus
		„ brevis
		„ magnus
		Biceps flexor cruris

2. **Movements of the Pelvis on the Thigh.**—It is to be noted that the several movements tabulated above refer to the movements of the femur at the hip-joint. The contraction of the same groups of muscles produces similar movements of the pelvis on the femur, exemplified in the various changes in the attitude of the pelvis in relation to the thigh and the vertebral column, which occur in locomotion.

3. **Movements at the Knee-Joint.**—The movements at the knee-joint are mainly flexion and extension. Flexion is much more powerful than extension. There is also a limited amount of rotation of the tibia. The movements are produced by certain of the muscles described above, associated with certain of the muscles of the leg.

a. Flexion	and	Extension.	*b.* Rotation inwards	and	Rotation outwards.
Sartorius		Quadriceps extensor	Sartorius		Biceps flexor cruris
Gracilis			Gracilis		
Semitendinosus			Semitendinosus		
Semimembranosus			Semimembranosus		
Biceps			Popliteus		
Gastrocnemius					
Plantaris					
Popliteus					

THE FASCIÆ AND MUSCLES OF THE LEG AND FOOT.

FASCIÆ.

The **superficial fascia** of the leg presents no special features except in the sole, where it is greatly thickened by pads of fat, particularly under the tuberosity of the os calcis, and under the balls of the toes. It is closely adherent to the plantar fascia, especially at the roots of the toes.

The **deep fascia** has numerous important attachments about the knee. Posteriorly it forms the popliteal fascia, and is joined by expansions from the tendons of the sartorius, gracilis, semitendinosus, and biceps muscles. In front of the knee it is attached to the patella, the ligamentum patellæ, and the tubercle of

the tibia; laterally it is connected to the tuberosities of the tibia and the head of the fibula, and forms the **lateral patellar ligaments**, broad fascial bands which pass obliquely from the sides of the patella to the tuberosities of the tibia, and are joined by fibres of the vasti muscles. Passing down the leg, the fascia blends over the inner surface of the tibia with the periosteum of the bone. It extends round the outer side of the leg from the anterior to the internal border of the tibia, binding together and giving origin to the muscles, and gaining an attachment to the lower part of the shaft of the fibula. **Two septa** pass from its deep surface; one septum, attached to the anterior border of the fibula, encloses the musculo-cutaneous nerve, and separates the extensor from the peronei muscles. The other septum is attached to the posterior border of the fibula, and separates the peronei from the flexor muscles. From the last-named septum another extends across the back of the leg, forms a partition between the superficial and deep flexor muscles, and encloses the posterior tibial vessels and nerves. It gives rise to a subordinate septum attached to the vertical line of the tibia and the oblique line of the fibula, which separate the tibialis posticus muscle from the flexors of the toes on either side.

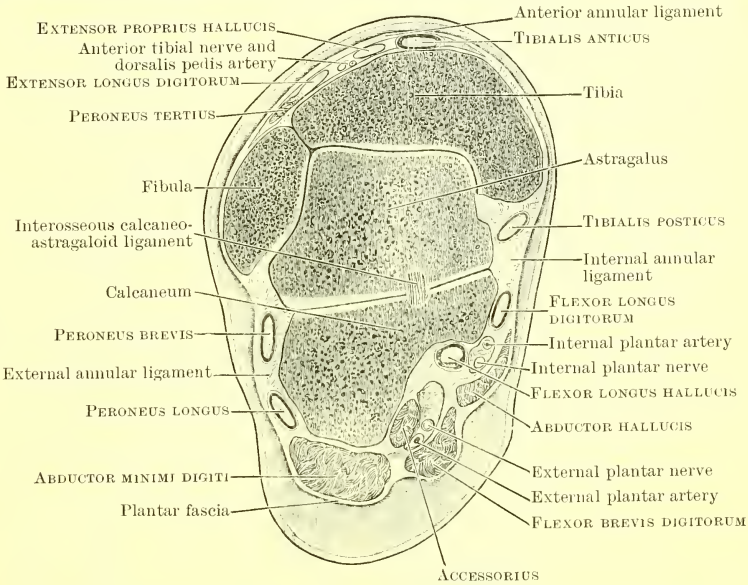


Fig. 293.—Coronal Section through the left Ankle-Joint, Astragalus, and Calcaneum.

At the ankle the deep fascia is strengthened by additional transverse fibres; it is attached to the malleoli and the os calcis, and gives rise to the **annular ligaments.**

The **internal annular ligament** stretches between the internal malleolus and the tuberosity of the os calcis. While it is continuous at its upper border with the general investment of the deep fascia of the leg, it is chiefly formed by the septal layer covering the deep muscles on the back of the leg. It sometimes gives insertion to the plantaris muscle. It is continuous below with the plantar fascia, and gives origin to the abductor hallucis muscle. It is pierced by the calcanean vessels and nerve. Along with the posterior tibial vessels and nerve, the tendons of the tibialis posticus, flexor longus digitorum, and flexor longus hallucis, pass beneath it, each enclosed in a separate synovial sheath.

The **external annular ligament**, much smaller, is a thickened band of the deep fascia stretching between the external malleolus and the os calcis. It binds down the tendons of the peronei, which occupy a space beneath the ligament, lined by a single synovial membrane.

The **anterior annular ligament** is in two parts. An **upper band**, broad and undefined at its upper and lower borders, stretches across the front of the ankle between the two malleoli. This band binds down to the lower end of the tibia the tendons of the tibialis anticus and extensor muscles of the toes. One synovial sheath is found beneath it, surrounding the tendon of the tibialis anticus.

On the dorsum of the foot, where the general covering of deep fascia is much thinner, a special well-defined band stretches over the extensor tendons. This **lower band** of the anterior annular ligament (fundiform or lambdoid ligament) has an attachment externally to the outer border of the greater process of the os calcis. It divides into two bands as it passes inwards over the dorsum of the foot—an

upper part, which joins the upper ligament and is attached to the internal malleolus, and a *lower part*, which passes across the dorsum of the foot, and joins the fascia of the sole at its inner border. Beneath this ligament are three special compartments with separate synovial sacs, one for the tibialis anticus tendon, a second for that of the extensor proprius hallucis, and a third for the extensor longus digitorum and peroneus tertius tendons. There are occasionally other additional bands of the deep fascia passing like the straps of a sandal across the dorsum of the foot.

The **plantar fascia** is of great importance. In the centre of the sole it forms a thick triangular band, attached posteriorly to the tuberosity of the os calcis. It spreads out anteriorly and separates into *five slips*, which are directed forwards to the bases of the toes. These slips as they separate are joined together by ill-defined bands of transverse fibres, which constitute the **superficial transverse metatarsal ligament.** The slip for each toe joins the tissue of the web of the toe and is continuous with the digital sheath. It splits to form a band of fibres directed forwards on each side of the toe to be attached to the sides of the metatarso-phalangeal articulation and the base of the first phalanx.

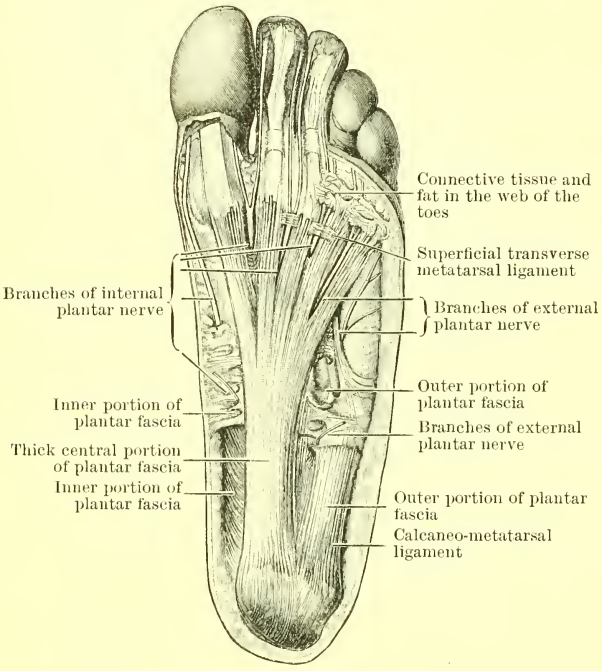


FIG. 294.—THE PLANTAR FASCIA AND PLANTAR CUTANEOUS NERVES.

This central portion of the plantar fascia assists in preserving the arch of the foot, by drawing the toes and the os calcis together.

On each side it is continuous with a much thinner layer which covers the lateral muscles of the sole, and joins the fascia of the dorsum of the foot at each border. It also gives rise to intermuscular septa, which pass upwards on each side of the flexor brevis digitorum, enclosing that muscle in a separate sheath, and giving investments on either side to the abductor muscles of the great and little toes. At the outer border of the foot the **calcaneo-metatarsal ligament**, a thickened band of the fascia, connects the tuberosity of the os calcis with the base of the fifth metatarsal bone.

The **digital sheaths**, though smaller, are the same in arrangement as those of the fingers. **Vaginal ligaments** are present in relation to the first and second phalanges.

THE MUSCLES OF THE LEG AND FOOT.

The muscles of the leg and foot are divisible into three series: (1) the extensor muscles on the front of the leg and dorsum of the foot; (2) the peronei on the outer side of the leg; and (3) the flexor muscles on the back of the leg and in the sole of the foot.

THE MUSCLES ON THE FRONT OF THE LEG AND DORSUM OF THE FOOT.

The muscles on the front of the leg and dorsum of the foot include two groups: (1) on the front of the leg, the tibialis anticus, long extensors of the toes and peroneus tertius; and (2) on the dorsum of the foot, the extensor brevis digitorum.

The **tibialis anticus** (m. tibialis anterior) **arises** by fleshy fibres from the outer

tuberosity and the upper two-thirds of the outer surface of the shaft of the tibia, from the interosseous membrane, from the fascia over it, and from an intermuscular septum externally. The muscle ends in a strong tendon which passes over the dorsum of the foot, to be **inserted** into a facet on the anterior and inferior part of the inner surface of the internal cuneiform and the adjacent inner side of the base of the first metatarsal bone (Fig. 295, p. 379).

The muscle is superficially placed along the outer side and front of the tibia,

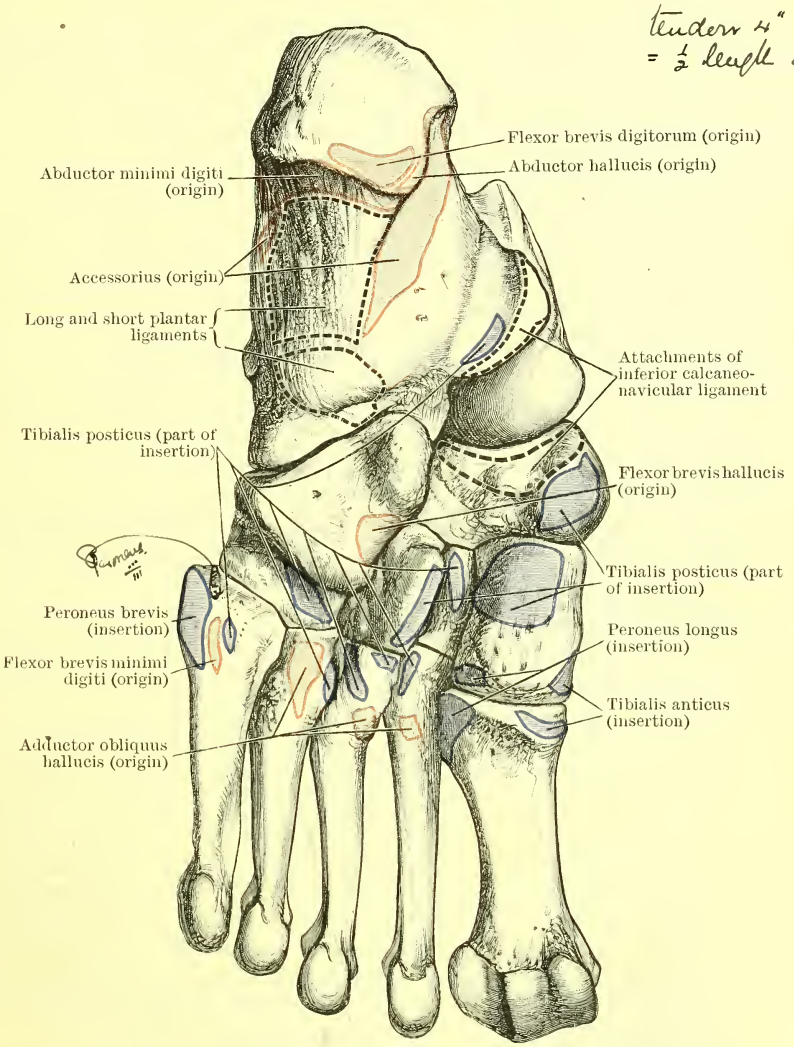


FIG. 295.—MUSCLE-ATTACHMENTS TO TARSUS AND METATARSUS (Plantar Aspect).

internal to the long extensors of the toes and the anterior tibial vessels and nerve. Its tendon occupies special compartments beneath both upper and lower parts of the anterior annular ligament, enclosed in a separate, single, synovial sac.

The **tibio-fascialis anticus** is a separated portion of the muscle occasionally present, inserted into the fascia on the dorsum of the foot.

The **extensor longus digitorum arises** by fleshy fibres from the outer side of the external tuberosity of the tibia, from the upper two-thirds or more of the anterior surface of the shaft of the fibula, from the fascia over it, and from intermuscular septa on either side. It gives rise to a tendon which passes beneath the anterior annular ligament, and in front of the ankle subdivides into four tendons, **inserted** into the four outer toes, exactly in the same way as the corresponding tendons in the hand (see p. 347). They form membranous expansions on the

dorsum of the first phalanx, joined by the tendons of the extensor brevis digitorum, lumbricales, and interossei, which separate into one central and two lateral slips, attached respectively to the middle and terminal phalanges.

The muscle is superficial, and is placed external to the tibialis anticus and extensor proprius hallucis, and internal to the peronei muscles. The musculo-cutaneous nerve is on its outer side. It conceals the anterior tibial vessels and nerve. The tendon occupies a separate compartment along with the peroneus tertius beneath the lower part of the anterior annular ligament, invested by a special synovial membrane.

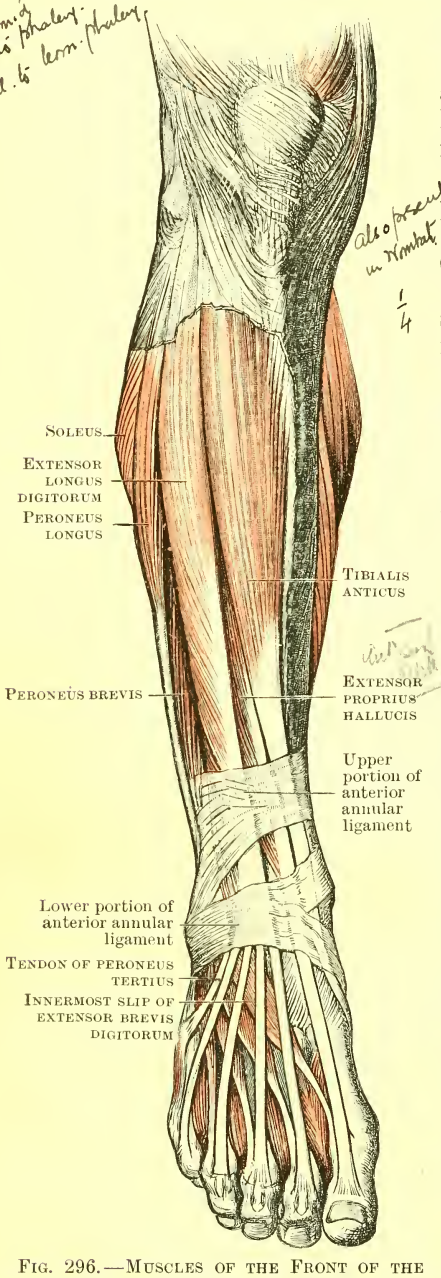


Fig. 296.—Muscles of the Front of the Right Leg and Dorsum of the Foot.

The **peroneus tertius** is a separated portion of the extensor longus digitorum. It is an essentially human muscle. It **arises** (inseparably from the extensor longus digitorum) from the lower part of the anterior surface of the fibula, from the interosseous membrane, and from the intermuscular septum external to it. The tendon of the muscle is **inserted** into the dorsal aspect of the base of the fifth metatarsal bone. It accompanies the extensor longus digitorum beneath the anterior annular ligament, and lies external to the tendons of that muscle on the dorsum of the foot.

The **extensor proprius hallucis muscle** (m. extensor hallucis longus) **arises** by fleshy fibres from the front of the fibula in its middle three-fifths, internal to the origin of the extensor longus digitorum, and for a corresponding extent from the interosseous membrane. Its tendon passes over the dorsum of the foot, to be **inserted** into the base of the terminal phalanx of the great toe. In the leg the muscle is deeply placed between the tibialis anticus and extensor longus digitorum. It conceals the anterior tibial vessels and nerve, and crosses the termination of the anterior tibial artery in front of the ankle-joint. It is invested by a special synovial sac as it lies beneath the lower part of the anterior annular ligament. On the dorsum of the foot the tendon is placed on the inner side of the dorsalis pedis artery.

The **extensor longus primi internodii** and **extensor ossis metatarsi hallucis** are occasional separate slips of this muscle inserted into the bones of the great toe.

The **extensor brevis digitorum** **arises** on the dorsum of the foot by short tendinous and fleshy fibres from a special impression on the upper surface of the greater process of the os calcis, and from the deep surface of the lower band of the anterior annular ligament.

It usually gives rise to four fleshy bellies, from which narrow tendons are directed forwards and inwards, to be **inserted** into the four inner toes. The three outer tendons join those of the long extensor muscle to form the membranous expansions on the dorsum of the toes. The *innermost tendon* is inserted separately into the base of the first phalanx of the great toe.

The muscle is covered by the lower band of the anterior annular ligament, and by the tendons of the extensor longus digitorum and peroneus tertius; the slip of the muscle passing to the great toe crosses over the dorsalis pedis artery.

The Muscles on the Outer Side of the Leg.

The muscles on the outer side of the leg comprise the peronei—longus and brevis.

The **peroneus longus** arises by fleshy fibres from the head and the upper two-thirds of the outer surface of the shaft of the fibula, from intermuscular septa on either side, and from the fascia over it. It forms a stout tendon, which hooks round the external malleolus, crosses the outer side of the os calcis, and passing through the groove on the cuboid bone, is directed across the sole of the foot to be **inserted** into the outer sides of the internal cuneiform and the base of the first metatarsal bones (Fig. 295, p. 379). The muscle is placed superficially in the leg, and is separated by intermuscular septa from the extensor longus digitorum and peroneus brevis in front, and the soleus and flexor longus hallucis behind. It partially conceals the peroneus brevis, along with which it passes beneath the external annular ligament, invested by a common synovial sheath. As it enters the sole of the foot a *fibro-cartilage* is formed in the tendon, which plays over a smooth tubercle on the cuboid bone, a bursa intervening. In its passage across the foot the tendon is enclosed in a fibrous sheath derived from the inferior calcaneo-cuboid ligaments and the tibialis posticus tendon, and is concealed by the first three layers of the muscles of the sole.

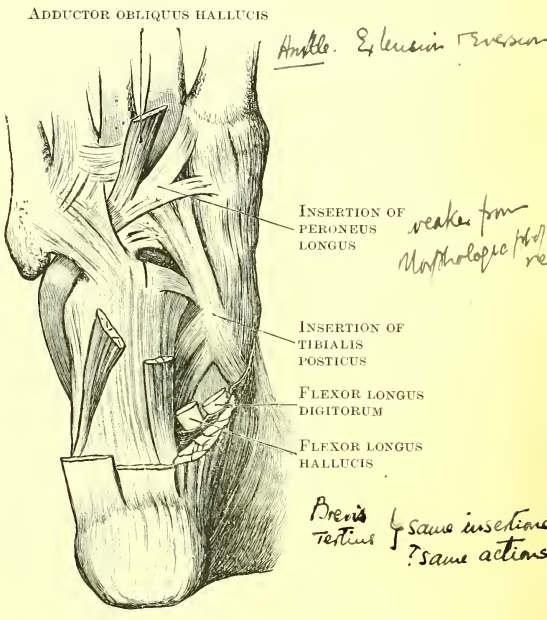


Fig. 297.—The Insertions of the Peroneus Longus and Tibialis Posticus Muscles in the Sole of the Right Foot.

The **peroneus brevis** arises by fleshy fibres from the lower two-thirds of the outer surface of the shaft of the fibula, and from an intermuscular septum along its anterior border. Its tendon passes over the back of the external malleolus and the outer side of the os calcis, to be **inserted** into the tubercle and dorsal surface of the base of the fifth metatarsal bone. In the leg the peroneus brevis lies behind the extensor longus digitorum and peroneus tertius, and in front of the peroneus longus, which partially overlaps it. The tendon lies directly behind the external malleolus beneath the external annular ligament, invested by a synovial sheath common to it and the peroneus longus.

The peroneus longus and brevis may be fused together, or additional slips may be present, as **peroneus accessorius, peroneus quinti digiti, peroneo-calcaneus externus,** and **peroneo-cuboideus.**

The Muscles on the Back of the Leg.

The muscles on the back of the leg are divisible into two layers: (1) a **superficial set**, consisting of the gastrocnemius and soleus (the so-called triceps muscle of the leg), and the plantaris; and (2) a **deep set**, consisting of the popliteus, flexor longus digitorum, tibialis posticus, and flexor longus hallucis.

The **gastrocnemius arises** by *two heads*, inner and outer, by means of strong tendons which are prolonged over the surface of the muscle. The outer head arises from an impression on the upper and posterior part of the outer surface of the external condyle, and from the lower end of the external supra-condyloid ridge; while the inner head arises from a prominent rough mark on the popliteal space of the femur above the internal condyle and from the surface between that and the

adductor tubercle. Each head has an additional origin from the back of the capsule of the knee-joint. A bursa lies beneath each tendon of origin. Each fleshy belly of the muscle is **inserted** into a broad membranous tendon, prolonged upwards on its deep surface for some distance. The inner head is the larger.

The **tendo Achillis** is formed by the union of the two membranous insertions of the bellies of the gastrocnemius. Prolonged upwards beneath the separate bellies, the tendon forms a broad membranous band connecting together the lower parts of the two bellies. Narrowing gradually, and becoming thicker in the lower half of the leg, the tendon is finally **inserted** into the intermediate surface on the posterior aspect of the os calcis. A bursa lies beneath the tendon at its insertion. The tendo Achillis also affords insertion to the soleus and (sometimes) the plantaris muscles.

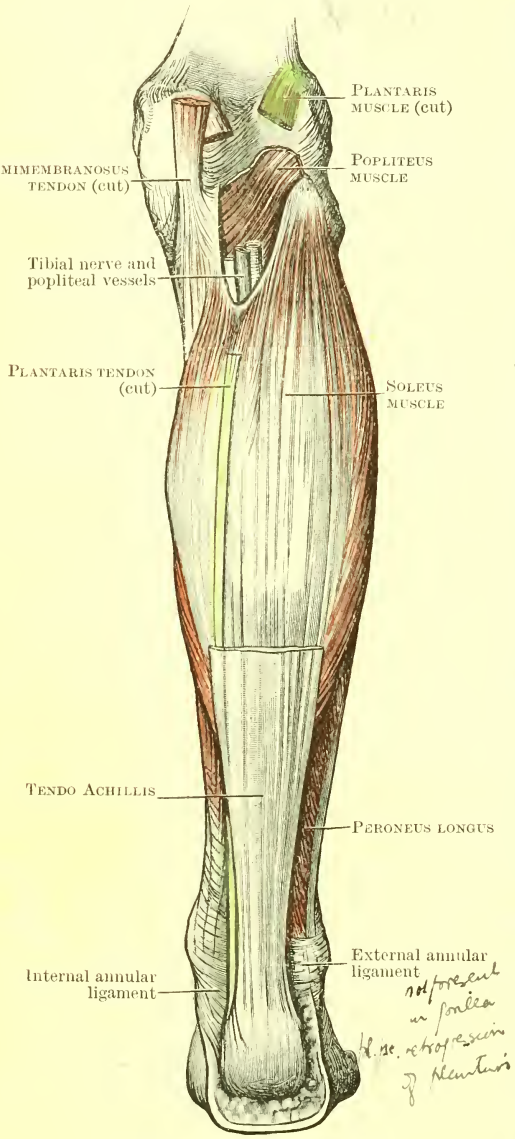


Fig. 298.—The Soleus Muscle.

The gastrocnemius is superficial except at its origin. The inner head is concealed by the semitendinosus and semimembranosus muscles, and partially covers the popliteal vessels and the tibial nerve in the lower part of their course. It forms part of the inner boundary of the popliteal space. The outer head is concealed partially by the biceps tendon and the peroneal nerve, and covers the plantaris muscle, the popliteal vessels, and the tibial nerve. It forms part of the outer boundary of the popliteal space. The two bellies are for the most part in close contact, the external saphenous vein occupying the interval between them. The tendo Achillis in the lower half of the leg partially conceals the soleus and the deeper muscles. The plantaris tendon lies along its inner border.

The **plantaris** arises by fleshy fibres from the external supra-condyloid ridge of the femur for about an inch at its lower end, from the adjacent part of the popliteal space of the femur, and from the posterior ligament of the knee-joint. It forms a narrow fleshy slip which ends in a tendon extending down the back of the leg, to be **inserted** into the inner side of the tuberosity of the os calcis, or the tendo Achillis, or the internal annular ligament. The tendon of the muscle is capable of considerable lateral extension. The plantaris lies between the outer head of the gastrocnemius and the soleus, and crosses the popliteal vessels and the tibial nerve. In the lower half of the leg its tendon lies along the inner border of the tendo Achillis. The muscle is not always present.

The **soleus** has a triple **origin** by means of short tendinous and fleshy fibres: (1) from the posterior surface of the head and the shaft of the fibula in its upper third; (2) from a fibrous arch stretching over the popliteal vessels and tibial nerve between the tibia and fibula; and (3) from the oblique line and middle third of

the inner border of the tibia (Fig. 299, p. 383). From this origin the upper muscular fibres are directed downwards to join a tendon placed on the superficial aspect of the muscle, which is **inserted** into the tendo Achillis; the lower fibres are inserted directly into the tendo Achillis to within one or two inches of the os calcis.

The muscle is concealed by the gastrocnemius, plantaris, and tendo Achillis in nearly its whole extent. It is partially superficial on each side of the gastrocnemius

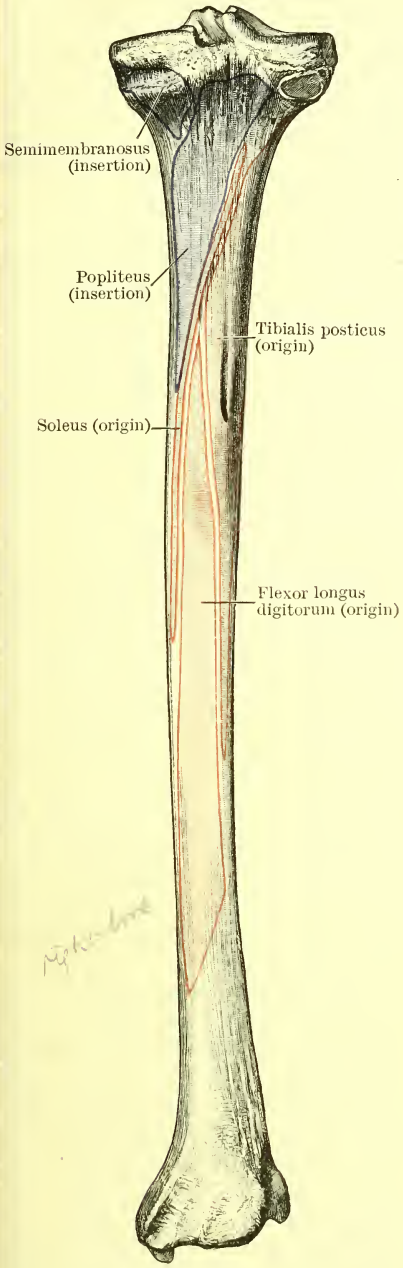


FIG. 299.—MUSCLE-ATTACHMENTS TO THE POSTERIOR SURFACE OF THE TIBIA.

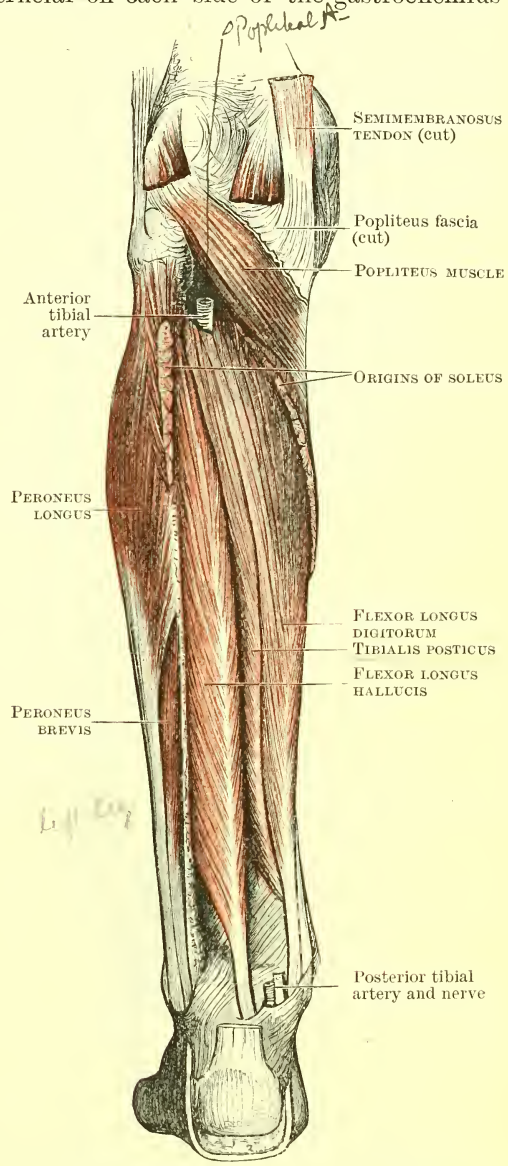


FIG. 300.—THE DEEP MUSCLES ON THE BACK OF THE LEFT LEG.

and tendo Achillis. The muscle covers the tibialis posticus and the flexor muscles of the toes as well as the posterior tibial vessels and nerve.

The **deep muscles** of the back of the leg comprise the popliteus, the long flexors of the toes, and the tibialis posticus.

The **popliteus** is deeply placed behind the knee. It **arises** by a stout tendon from a rough impression in front of a groove on the outer aspect of the external

condyle of the femur. This tendon passes between the external semilunar cartilage and the capsule of the knee-joint, and pierces the posterior ligament, from which it takes an additional fleshy origin. A bursa is placed beneath the tendon, which communicates usually with the synovial cavity of the knee-joint. The muscle is **inserted** by fleshy fibres (1) into a triangular surface on the back of the tibia above the oblique line (except a small area below the fibular facet) (Fig. 299, p. 383), and (2) into the fascia over it (the popliteus fascia, derived from the tendon of the semimembranosus muscle). The popliteus is covered at its origin by the capsule of the knee-joint. Posteriorly it is concealed by the gastrocnemius and plantaris muscles, and by the popliteal vessels and the tibial nerve. Its lower border corresponds to the point of bifurcation of the popliteal artery and the origin of the soleus muscle.

The **popliteus minor** is a small occasional muscle attached to the popliteal space of the femur and the posterior ligament of the knee-joint.

The **flexor longus digitorum** occupies both the back of the leg and the sole of the foot. Its **origin** is by fleshy fibres from the posterior surface of the shaft of the tibia in its middle three-fifths, below the oblique line, and internal to the vertical line and the origin of the tibialis posticus, from the fascia over it, and from an intermuscular septum on each side (Fig. 299, p. 383). Its tendon, after passing beneath the internal annular ligament, enters the sole of the foot, and divides into four subordinate tendons, which are **inserted** into the four outer toes in precisely the same manner as the flexor profundus digitorum is inserted in the hand. Each tendon enters the digital sheath of the toe, perforates the tendon of the flexor brevis digitorum, and is inserted into the base of the terminal phalanx. **Ligamenta accessoria** (**longa** and **brevia**) are present as in the hand. Associated with this muscle in the sole of the foot are the lumbricales and accessorius muscles.

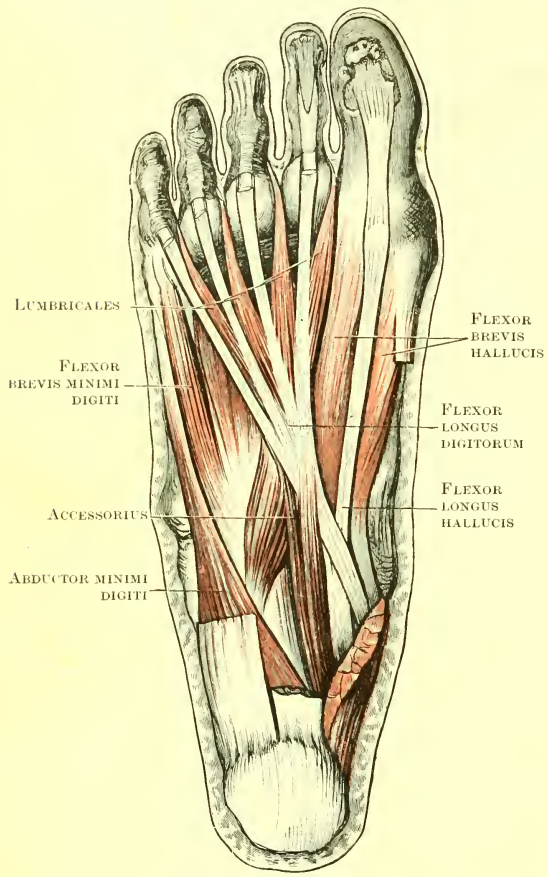


FIG. 301.—THE MUSCLES OF THE RIGHT FOOT (after removal of the first layer).

The **lumbricales** are four small muscles **arising** in association with the tendons of the flexor profundus digitorum in the sole. The *first muscle* arises by a single origin from the tibial side of the tendon of the flexor longus digitorum for the second toe; the *other three* arise by two heads from the adjacent sides of all four tendons. Each muscle is **inserted** into the dorsal expansion of the extensor tendon, the metatarso-phalangeal capsule, and the base of the first phalanx, precisely as in the case of the lumbrical muscles of the hand. Each muscle passes forwards on the tibial side of the corresponding toe, superficial to the transverse metatarsal ligament.

The **flexor accessorius muscle** (m. quadratus plantæ) **arises** by two heads: (1) the outer tendinous head springs from the outer border of the inferior surface of the os calcis and from the outer border of the long plantar ligament; (2) the inner head, which is fleshy, arises from the concave inner surface of the os calcis in its whole extent, and from the inner border of the long plantar ligament (Fig. 295,

p. 379). The long plantar ligament separates the two origins. The two heads unite to form a flattened band, which is **inserted** into the upper aspect of the tendons of the flexor longus digitorum, and usually into those destined for the second, third, and fourth toes.

In the leg the flexor longus digitorum lies at first internal to the tibialis posticus, and is partially concealed by the soleus and tendo Achillis. Its tendon crosses over the tibialis posticus above the ankle-joint, passes beneath the internal annular ligament, invested by a special synovial sheath, and below the ligament crosses the plantar or superficial surface of the tendon of the flexor longus hallucis. As it passes over this tendon it receives from it a special band of fibres, usually associated with the tendons for the second and third toes.

In the sole of the foot the tendons of the flexor longus digitorum, along with the lumbricales and accessorius, and the flexor longus hallucis muscles, constitute the second layer of muscles of the sole. They are placed between the abductors of the great and little toes and the flexor brevis digitorum on the one hand, and the flexor brevis and adductors of the great toe on the other.

The **flexor longus hallucis arises** by fleshy fibres on the back of the leg from the lower two-thirds of the posterior surface of the shaft of the fibula, from the fascia over it, and from intermuscular septa on either side. Its tendon passes beneath the internal annular ligament enclosed in a special synovial sheath, and after grooving the back of the lower end of the tibia, the astragalus, and the under surface of the sustentaculum tali of the os calcis, it is directed forwards in the sole of the foot, to be **inserted** into the base of the terminal phalanx of the great toe.

The muscle is partially concealed in the leg by the soleus and tendo Achillis. It lies at its origin between the tibialis posticus and the peronei muscles, separated from the former by the peroneal artery. In the foot, concealed by the abductor hallucis, it crosses over the deep aspect of the tendon of the flexor longus digitorum, to which it is connected by a strong fibrous band destined for the tendons for the second and third toes. At the root of the great toe the tendon occupies the interval between the insertions of the flexor brevis hallucis.

The **tibialis posticus muscle** (m. tibialis posterior) has a fourfold fleshy **origin** in the leg. It arises (1) from the upper four-fifths of the shaft of the fibula between the oblique line and the interosseous border; (2) from the lower part of the outer tuberosity of the tibia and from the upper two-thirds of the shaft of the bone below the oblique line and between the vertical line and the interosseous border (Fig. 299, p. 383); (3) from the interosseous membrane; and (4) from the fascia over it and the septa on either side. The muscle gives rise to a strong tendon which passes beneath the internal annular ligament, invested by a special synovial sheath, and grooves the back of the internal malleolus, on its way to the inner border of the foot. The tendon then spreads out and is **inserted** by three bands into (1) the tubercle of the navicular bone and the plantar surfaces of the internal and middle cuneiform bones, (2) the plantar aspects of the second, third, fourth, and sometimes the fifth metatarsal bones, the middle and external cuneiform bones, and the groove on the cuboid, and (3) by a recurrent slip into the inner border of the sustentaculum tali of the os calcis from which a fibrous expansion passes outwards to join the inner border of the short plantar ligament (Fig. 302, p. 386).

In the leg the tibialis posticus is concealed, as it lies on the interosseous membrane between the tibia and fibula, by the superficial muscles and the posterior tibial vessels and nerve. It lies between the flexor longus hallucis and flexor longus digitorum, and is crossed by the tendon of the latter muscle just above the ankle. Just below the knee between its tibial and fibular origins is an angular space through which the anterior tibial vessels pass. In the foot its tendon is covered by the long flexor tendons and by the short flexor muscles of the great toe. The tendon is in contact with the inferior calcaneo-navicular ligament in the interval between the sustentaculum tali and the navicular bone.

The **peroneo-calcaneus** muscle, when present, **arises** from the fibula, and is **inserted** into the os calcis.

The Muscles in the Sole of the Foot.

The muscles in the sole of the foot are divisible into four layers placed beneath the plantar fascia.

First layer: Abductor hallucis, flexor brevis digitorum, abductor minimi digiti.

Second layer: Lumbricales and accessorius, together with the tendons of the flexor longus hallucis and flexor longus digitorum.

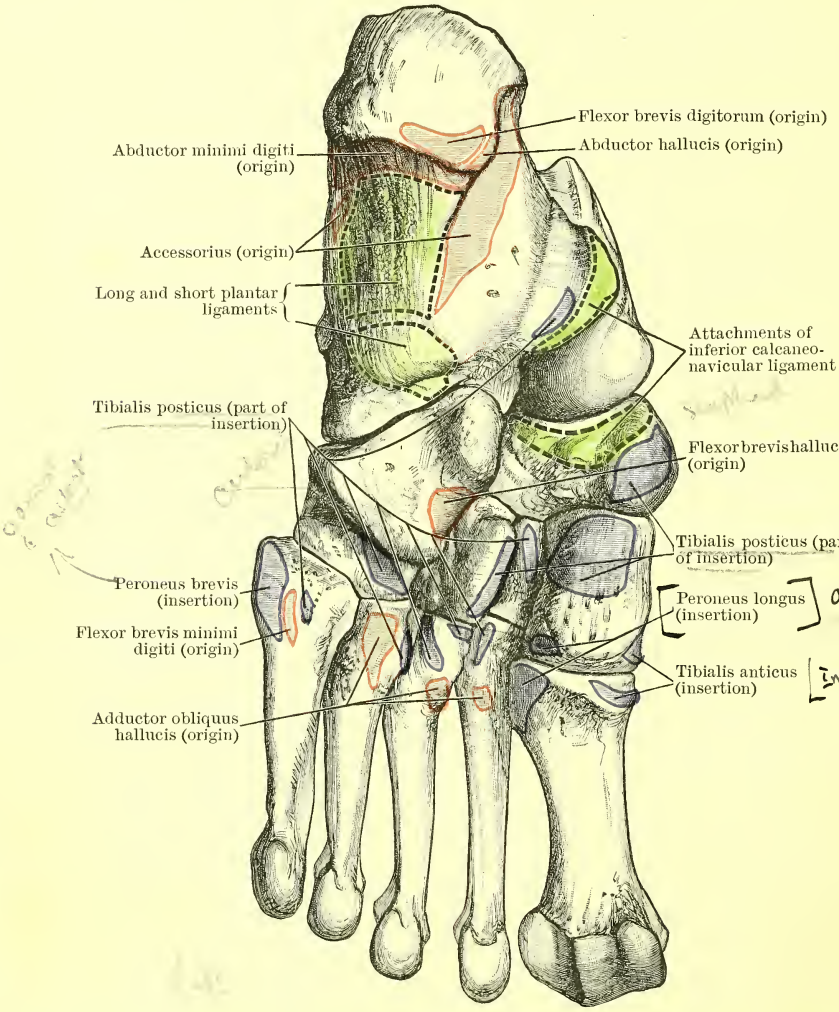


Fig. 302.—Muscle-Attachments to Tarsus and Metatarsus (Plantar Aspect).

Third layer: Flexor brevis hallucis, adductors of the great toe, and flexor brevis minimi digiti.

Fourth layer: Interossei (plantar and dorsal).

The **abductor hallucis** has a double **origin**, (1) by a short tendon from the inner side of the greater tubercle on the tuberosity of the os calcis (Fig. 302, p. 386), and (2) by fleshy fibres from the internal annular ligament, the plantar fascia which covers it, and the intermuscular septum between it and the flexor brevis digitorum. Lying superficially along the inner border of the sole, its tendon is **inserted**, along with part of the flexor brevis hallucis, into the inner side of the posterior end of the first phalanx of the great toe. The muscle lies beneath the plantar fascia, internal to the flexor brevis digitorum, and conceals the plantar vessels and nerves, and near its origin the long flexor tendons.

The **flexor brevis digitorum** has likewise a double **origin**: (1) by a short

tendon from the fore-part of the greater tubercle of the tuberosity of the os calcis (Fig. 302, p. 386), and (2) by fleshy fibres from the thick central part of the plantar fascia which covers it, and from the intermuscular septa on either side. Passing forwards, it gives rise to four slender tendons, which are **inserted** into the second phalanges of the four outer toes, after having been perforated, just as in the case of the tendons of the flexor sublimis digitorum of the hand, by the long flexor tendons. Placed in the centre of the sole beneath the plantar fascia, and between the abductor hallucis and abductor minimi digiti muscles, the muscle conceals the second layer of muscles and the external plantar vessels and nerve.

The **abductor minimi digiti** (m. abductor digiti quinti) has also a double **origin**: (1) by fleshy and tendinous fibres from the fore-part of both tubercles on the tuberosity of the os calcis, partly concealed by the flexor brevis digitorum (Fig. 302, p. 386), and (2) by fleshy fibres from the outer portion of the plantar

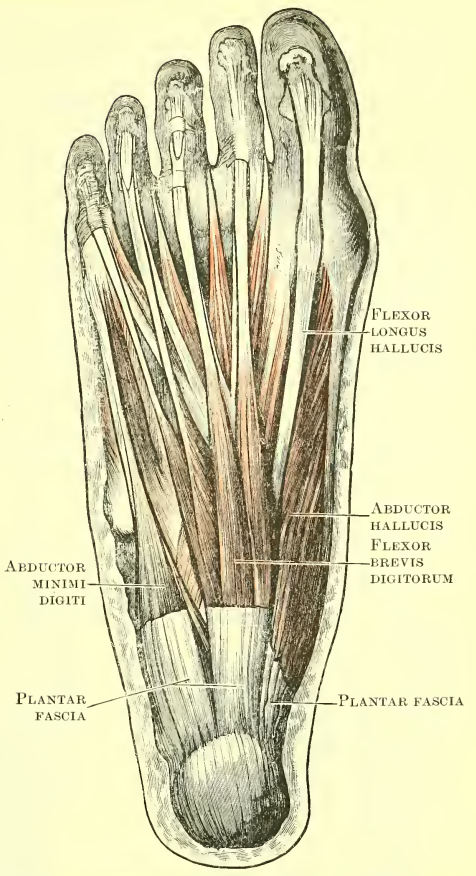


FIG. 303.—THE MUSCLES OF THE RIGHT FOOT (after removal of the plantar fascia).

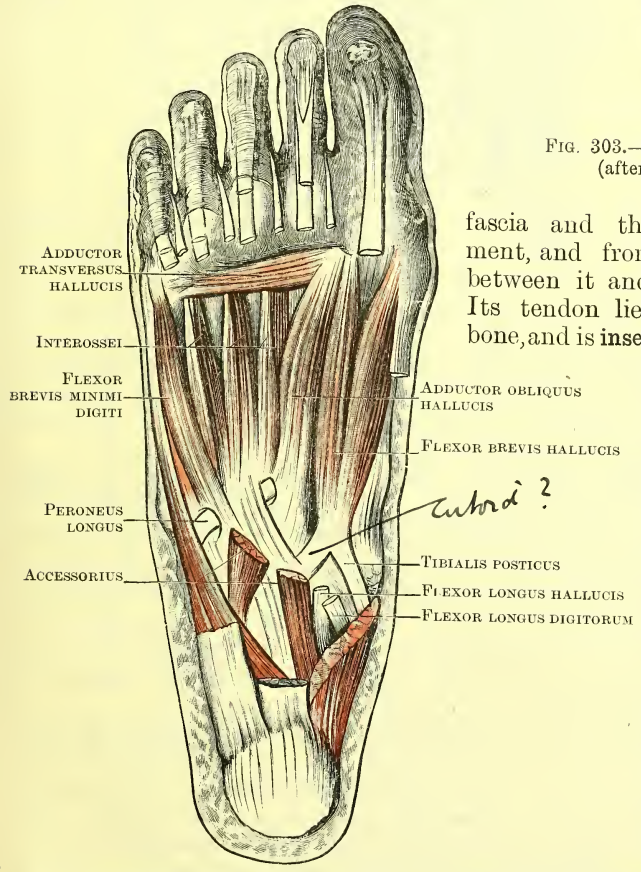


FIG. 304.—THE MUSCLES OF THE RIGHT FOOT (after removal of the second layer).

fascia and the calcaneo-metatarsal ligament, and from the intermuscular septum between it and the flexor brevis digitorum. Its tendon lies along the fifth metatarsal bone, and is **inserted** by a tendon into the outer side of the posterior end of the first phalanx of the little toe. The outermost fibres usually obtain an additional insertion into the outer side of the plantar surface of the fifth metatarsal bone. It lies on the outer side of the flexor brevis digitorum, and partially conceals the flexor brevis minimi digiti.

The tendons of the long flexors of the toes, the **lumbricales** and **accessorius muscles,** constituting the **second layer of muscles,** have already been described. Lying beneath the abductor hallucis and the flexor brevis digitorum, and separated from them by the

plantar vessels and nerves, they occupy the hollow of the tarsus and the space between the first and fifth metatarsal bones; their deep surfaces are in contact with the adductors of the great toe and the interossei muscles.

The **flexor brevis hallucis** arises by tendinous fibres (1) from the inner part of the under surface of the cuboid bone (Fig. 302, p. 386), and (2) from the tendon of the tibialis posticus. Directed forwards over the first metatarsal bone, the muscle separates into two parts, between which is the tendon of the flexor longus hallucis. Each portion gives rise to a tendon which is **inserted** into the corresponding side of the base of the first phalanx of the great toe; in each tendon, under the metatarso-phalangeal articulation, a sesamoid bone is developed. The inner tendon is united with the insertion of the abductor, the outer tendon with the insertions of the adductor muscles of the great toe.

The **adductor obliquus hallucis** arises by fleshy and short tendinous fibres (1) from the sheath of the peroneus longus, and (2) from the plantar surfaces of the posterior extremities of the second, third, and fourth metatarsal bones (Fig. 302, p. 386). Occupying the hollow of the foot, on a deeper plane than the long flexor tendons and lumbricales, and separated from the interossei by the plantar arch, it is placed on the outer side of the flexor brevis hallucis, and is directed obliquely inwards and forwards, to be **inserted** on the outer side of the base of the first phalanx of the great toe between and along with the flexor brevis and adductor transversus hallucis. The muscle forms one side of a triangular space in the sole through which the external plantar vessels and nerve pass.

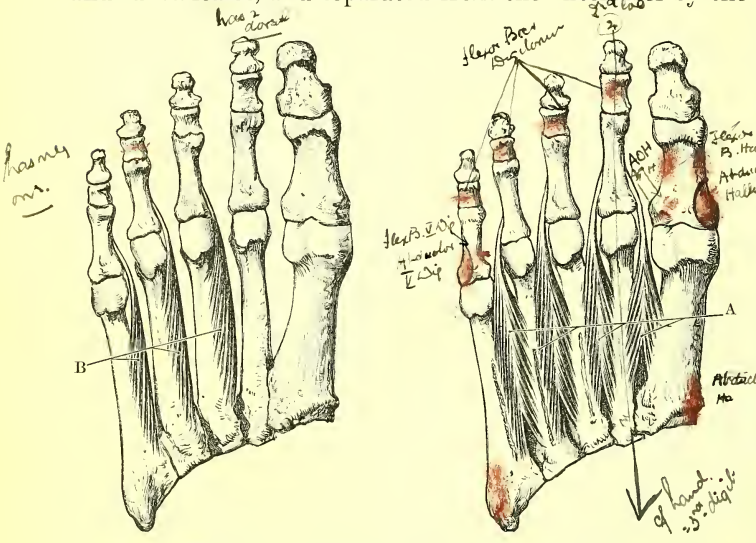


Fig. 305.—Interosseous Muscles of the Foot.

A, Dorsal muscles (plantar aspect); B, Plantar muscles of the right foot.

The **adductor transversus hallucis** arises from (1) the capsules of the outer four metatarso-phalangeal articulations and (2) the transverse metatarsal ligament. Directed transversely inwards, under cover of the flexor tendons and lumbricales, the muscle is **inserted**, along with the adductor obliquus (from which it is separated by an angular interval), into the outer side of the base of the first phalanx of the great toe.

The **flexor brevis minimi digiti** (m. flexor brevis digiti quinti) **arises** from (1) the sheath of the peroneus longus, and (2) the base of the fifth metatarsal bone (Fig. 302, p. 386). Partially concealed by the abductor minimi digiti, the muscle passes along the fifth metatarsal bone, to be **inserted**, in common with that muscle, into the outer side of the base of the first phalanx of the little toe.

The **interossei muscles** of the foot resemble those of the hand except in one respect. In the hand the line of action of the muscles is the middle line of the middle finger. In the foot the *second toe* is the digit round which the muscles are grouped, and their attachments and their actions differ accordingly.

There are four dorsal and three plantar muscles, which occupy together the four interosseous spaces, and project into the hollow of the foot.

The **four dorsal muscles**, one in each interosseous space, **arise** by two heads each from the shafts of the metatarsal bones. Each gives rise to a tendon, which, after passing dorsal to the transverse metatarsal ligament, is **inserted** on the dorsum of the foot into the side of the first phalanx, the metatarso-phalangeal capsule, and the dorsal expansion of the extensor tendon. The *first* and *second muscles* are inserted

into the second toe on the tibial and fibular sides respectively. The *third* and *fourth muscles* are inserted into the third and fourth toes on their fibular sides.

The **three plantar muscles** occupy the three outer interosseous spaces. Each **arises** by a single head from the tibial side of the third, fourth, and fifth metatarsal bones respectively. Each ends in a tendon which passes dorsal to the transverse metatarsal ligament, and is **inserted**, in the same manner as the dorsal muscles, into the third, fourth, and fifth toes on their tibial side.

Nerve-Supply of the Muscles of the Leg and Foot.

Muscles.	Nerves.	Origin.
Tibialis anticus Extensor proprius hallucis Extensor longus digitorum Peroneus tertius	anterior tibial	L. 4. 5. S. 1.
Peroneus longus Peroneus brevis	musculo-cutaneous	L. 4. 5. S. 1.
Extensor brevis digitorum	anterior tibial	L. 4. 5. S. 1.
Plantaris Popliteus Gastrocnemius Soleus	tibial	L. 4. 5. S. 1. S. 1. 2.
Soleus	posterior tibial	L. 5. S. 1. 2.
Flexor longus digitorum	posterior tibial	L. 5. S. 1.
Tibialis posticus	posterior tibial	L. 5. S. 1.
Flexor longus hallucis	posterior tibial	L. 5. S. 1. 2.
Abductor hallucis Flexor brevis digitorum Flexor brevis hallucis First lumbricalis	internal plantar	L. 4. 5. S. 1.
Second, third, and fourth lumbricales Flexor accessorius Adductores hallucis Interossei Flexor brevis minimi digiti Abductor minimi digiti	external plantar	S. 1. 2.

Action of the Muscles of the Leg and Foot.

The muscles of the leg and foot act chiefly in the movements of the ankle-joint (assisted by movements of the inter-tarsal joints); of the metatarso-phalangeal joints (assisted by movements of the tarso-metatarsal and inter-metatarsal joints); and of the inter-phalangeal joints of the several toes.

I. Tibio-Fibular Articulations.—The upper tibio-fibular articulation is only capable of slight gliding movement, occasioned by the action of the biceps and popliteus and the muscles arising from the fibula.

II. Movements at the Ankle-Joint.—The movements at the ankle-joint are movements of flexion and extension of the foot on the leg, along with inversion and eversion (only during extension). These movements are produced at the ankle, aided by movements in the inter-tarsal joints, and are occasioned by the following muscles:—

a. Flexion.	Extension.	*b.* Inversion.	Eversion.
Tibialis anticus Extensor communis digitorum Extensor proprius hallucis Peroneus tertius	Gastrocnemius Plantaris Soleus Tibialis posticus Peroneus longus Peroneus brevis Flexor longus digitorum Flexor longus hallucis	Tibialis anticus Tibialis posticus	Peroneus tertius Peroneus longus Peroneus brevis

III. Movements of the Toes.—*A.* **At the Metatarso-Phalangeal Joints** (assisted by movements at the tarso-metatarsal and inter-metatarsal joints).—These movements are flexion and extension, abduction and adduction (in a line corresponding to the axis of the second toe).

a. **Flexion.**	**Extension.**
Flexor longus digitorum	Extensor longus digitorum
Accessorius	
Lumbricales	Extensor brevis digitorum
Flexor longus hallucis	
Flexor brevis hallucis	Extensor proprius hallucis
Flexor brevis digitorum	
Flexor brevis minimi digiti	
Interossei	

b. **Abduction.**	**Adduction.**
(*From and to the middle line of the second toe.*)	
Abductor hallucis	Adductores hallucis
Dorsal interossei	Plantar interossei
Abductor minimi digiti	

B. **At the inter-phalangeal joints** the movements are limited to flexion and extension.

Flexion.	**Extension.**
Flexor brevis digitorum (*acting on the first joint*)	Extensor longus digitorum
Flexor longus digitorum (*acting on both joints*)	Extensor brevis digitorum (*acting on both joints*)
Flexor longus hallucis (*acting on the hallux*)	Interossei (*acting on both joints*)
	Lumbricales (*acting on both joints*)
	Extensor proprius hallucis (*acting on both joints*)

Movements of the Lower Limb generally.

The characteristic features of the lower limb are stability and strength, and its muscles and joints are both subservient to the functions of transmission of weight and of locomotion. In the standing position the centre of gravity of the trunk falls between the heads of the femora, and is located about the middle of the body of the last lumbar vertebra. It is transmitted through the bones of the lower limb to the arch of the foot, where the astragalus distributes it backwards through the os calcis to the heel, and forwards through the tarsus and metatarsus to the balls of the toes.

Locomotion.—The three chief means of progression are walking, running, and leaping. In **walking**, the body and its centre of gravity are inclined forwards, the trunk oscillates from side to side as it is supported alternately by each foot, the arms swing alternately with the corresponding leg, and one foot is always on the ground. The act of progression is performed by the leg, aided in two ways by gravity. The movements of the leg are as follows: At the beginning of a step, one leg, so to speak, "shoves off;" the heel is raised and the limb is extended. By the action of the muscles flexing the hip and knee-joint, and extending the ankle-joint and toes, this limb is raised from the ground sufficiently to clear it, and passes forwards by the action of gravity, aided by the force given to the movement by the extensor muscles. After passing the line of the centre of gravity the flexion of the joints ceases, the muscles relax, and the limb gradually returns to the ground. The other limb then passes through the same cycle, the weight of the body now resting on the limb which is in contact with the ground. As the foot reaches the ground it, as it were, rolls over it; the heel touches it first, then the sole, and lastly, as the foot leaves the ground again, only the toes. In **running**, the previous events are all exaggerated. The time of the event is diminished, while the force and distance are increased. Both feet are off the ground at one time; the action of flexors and extensors alternately is much more powerful, so that on the one hand the knees are drawn upwards to a greater extent in the forward movement, and not the whole foot, but only the toes reach the ground in the extension of the limb. The attempt is made to bring the foot to the ground in front of the line of the centre of gravity. At the same time the trunk is sloped forwards much more than in walking. In **leaping**, the actions of the limbs are still more exaggerated. The movements of flexion of the limb are still more marked, and the foot reaches the ground still farther in front of the line of the centre of gravity.

AXIAL MUSCLES.

THE FASCIÆ AND MUSCLES OF THE BACK.

THE FASCIÆ OF THE BACK.

The general fascial investments of the back have been described along with the superficial muscles associated with the shoulder-girdle (p. 318). The latissimus dorsi muscle has been described as arising in large part from the **vertebral aponeurosis**. This is a strong fibrous lamina which conceals the erector spinæ muscle. In the loin it extends from the spines of the lumbar vertebræ outwards to the interval between the last rib and the iliac crest, where it is concerned in forming the **lumbar fascia**. Below the loin the vertebral aponeurosis is attached to the iliac crest, and more internally blends with the subjacent tendinous origin of the erector spinæ. The fascia can be followed upwards over the erector spinæ in the region of the thorax, where it is attached externally to the ribs and is continuous with the intercostal aponeuroses. In the lower part of the thorax it is replaced by muscular slips—the serratus posticus inferior; in the upper part of the thorax it passes beneath the serratus posticus superior and blends with the deep cervical fascia.

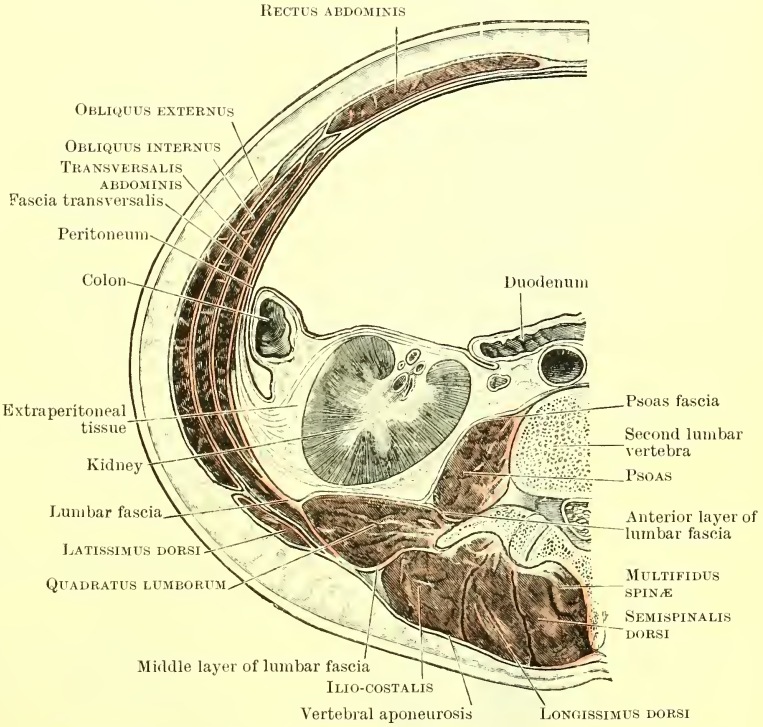


Fig. 306.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

The **lumbar fascia** is a narrow ligamentous band which connects the last rib to the iliac crest between the muscles of the back on the one hand and those of the abdominal wall on the other. It is formed by the union of three fascial strata, called respectively the **vertebral aponeurosis** or posterior layer, just described; the middle, and the anterior layers. The **middle layer** is a fascia which stretches outwards from the ends of the transverse processes of the lumbar vertebræ, between the erector spinæ behind and the quadratus lumborum muscle in front. The **anterior layer** is attached to the lumbar vertebræ near the bases of their transverse processes. It covers the front of the quadratus lumborum muscle, and separates it from the psoas. The **psoas fascia** is continuous at the outer border of the psoas muscle with the anterior layer of the lumbar fascia. At the outer borders of the quadratus lumborum and erector spinæ muscles the three layers are blended together to form the lumbar fascia, which in turn gives partial origin to the obliquus internus and transversalis abdominis muscles.

THE MUSCLES OF THE BACK.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral, (2) vertebro-costal, (3) vertebro-cranial, and (4) vertebral. They are in irregular strata, the most superficial muscles having the most widely spread attachments.

The first series of muscles of the back, connecting the axial skeleton to the upper limb, have already been described. They are arranged in two layers: (1) trapezius and latissimus dorsi superficially; (2) levator anguli scapulæ, and rhomboidei, beneath the trapezius.

The remaining muscles are almost entirely axial, and may be divided, according to position, into four groups: (1) serrati postici, superior and inferior, splenius capitis and splenius colli; (2) erector spinæ and complexus; (3) transverso-spinales (semispinalis and multifidus spinæ); and (4) the small deep muscles (rotatores, interspinales, intertransversales, and suboccipital muscles).

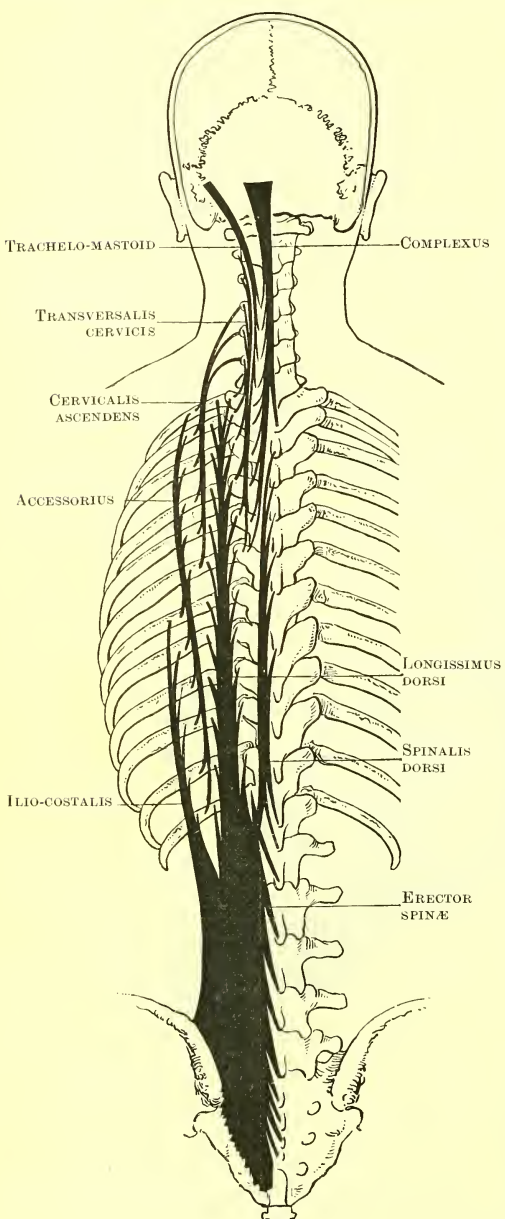


Fig. 307.—Schematic Representation of the Parts of the Erector Spinæ Muscle.

First Group.

The **serratus posticus superior** has a membranous **origin** from the ligamentum nuchæ and the spines of the last cervical and upper three or four thoracic vertebræ. It is directed obliquely downwards and outwards, to be **inserted** by separate slips into the second, third, fourth, and fifth ribs. The muscle is concealed by the vertebro-scapular muscles, and crosses obliquely the splenius, erector spinæ, and complexus. It lies superficial to the vertebral aponeurosis.

The **serratus posticus inferior** has a membranous **origin** through the medium of the vertebral aponeurosis from the last two thoracic and first two lumbar spinous processes. It forms four muscular bands which pass almost horizontally outwards to an **insertion** into the last four ribs. The muscular slips overlap one another from below upwards. The muscle is on the same plane as the vertebral aponeurosis, and is concealed by the latissimus dorsi.

The **splenius muscle** is a broad, flattened band which occupies the back of the neck and the upper part of the thoracic region. It **arises** from the ligamentum nuchæ (from the level of the fourth cervical vertebra downwards) and from the spinous processes of the last cervical and higher (four to six) thoracic vertebræ. Its fibres extend upwards and outwards into the neck, separating in their course into an upper and a lower part. The upper part forms the **splenius capitis**, which is **inserted** into the mastoid process and the outer part of the superior curved line of

the occipital bone (Fig. 312, p. 397). The lower part forms the **splenius colli** or **cervicis**, which is **inserted** into the posterior tubercles of the transverse processes of the upper three or four cervical vertebræ, behind the origin of the levator anguli scapulæ. The muscle is partially concealed by the trapezius and sterno-mastoid, and appears between them in the floor of the posterior triangle of the neck (splenius capitis). It is covered by the rhomboid muscles, levator anguli scapulæ, and serratus posticus superior. It conceals the transversalis cervicis, trachelo-mastoid, and complexus muscles.

Second Group.

The **erector spinæ** (m. sacro-spinalis) possesses vertebral, vertebro-cranial, and vertebro-costal attachments. It consists of an elongated mass composed of separated slips extending from the sacrum to the skull. Simple at its origin, it becomes more and more complex as it is traced upwards towards the head. It **arises** (1) by fleshy fibres from the iliac crest; (2) from the posterior sacro-iliac ligament; and (3) by tendinous fibres continuous with the former from the iliac crest, the back of the sacrum, and the spines of the upper sacral and all the lumbar vertebræ. Its fibres extend upwards through the loin, enclosed between the posterior and middle layers of the lumbar fascia, and separate into two columns—an outer portion derived from the external fleshy origin, the **ilio-costalis**, and an inner portion comprising the remaining larger part of the muscle, the **longissimus dorsi**.

The **ilio-costalis** (m. ilio-costalis lumborum) is **inserted** by six slender slips into the lower six ribs.

Internal to the insertion of each is the origin of a slip of the **accessorius muscle**

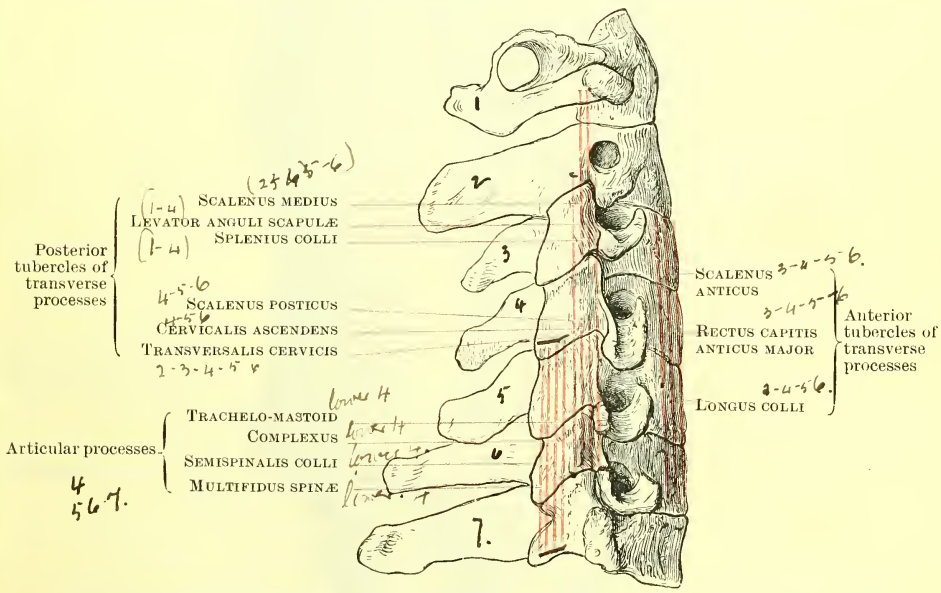


Fig. 308.—Scheme of Muscular-Attachments to the Transverse Processes of the Cervical Vertebræ.

(m. ilio-costalis dorsi), which, **arising** from the lower six ribs internal to the ilio-costalis, is **inserted** in line with it by similar slips into the upper six ribs.

The **cervicalis ascendens** (m. ilio-costalis cervicis) **arises** in the same way by six slips from the upper six ribs, internal to the insertions of the accessorius. It forms a narrow band, which, extending into the neck, is **inserted** into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, behind the scalenus posticus. The ilio-costalis, accessorius, and cervicalis ascendens form together a continuous muscular column, and constitute the outermost group of the component elements of the erector spinæ.

The **longissimus dorsi** is the largest element in the erector spinæ muscle.

With its cervical prolongations—the transversalis cervicis and trachelo-mastoid—it forms the middle column of the erector spinæ. Mostly tendinous on the surface at its origin, it becomes fleshy in the upper part of the loin. It is thickest in the loin, and becomes thinner as it passes upwards in the back between the column formed by the ilio-costalis, etc., externally, and the spinalis dorsi internally. It is **inserted** by two series of slips, inner and outer, externally into nearly all the

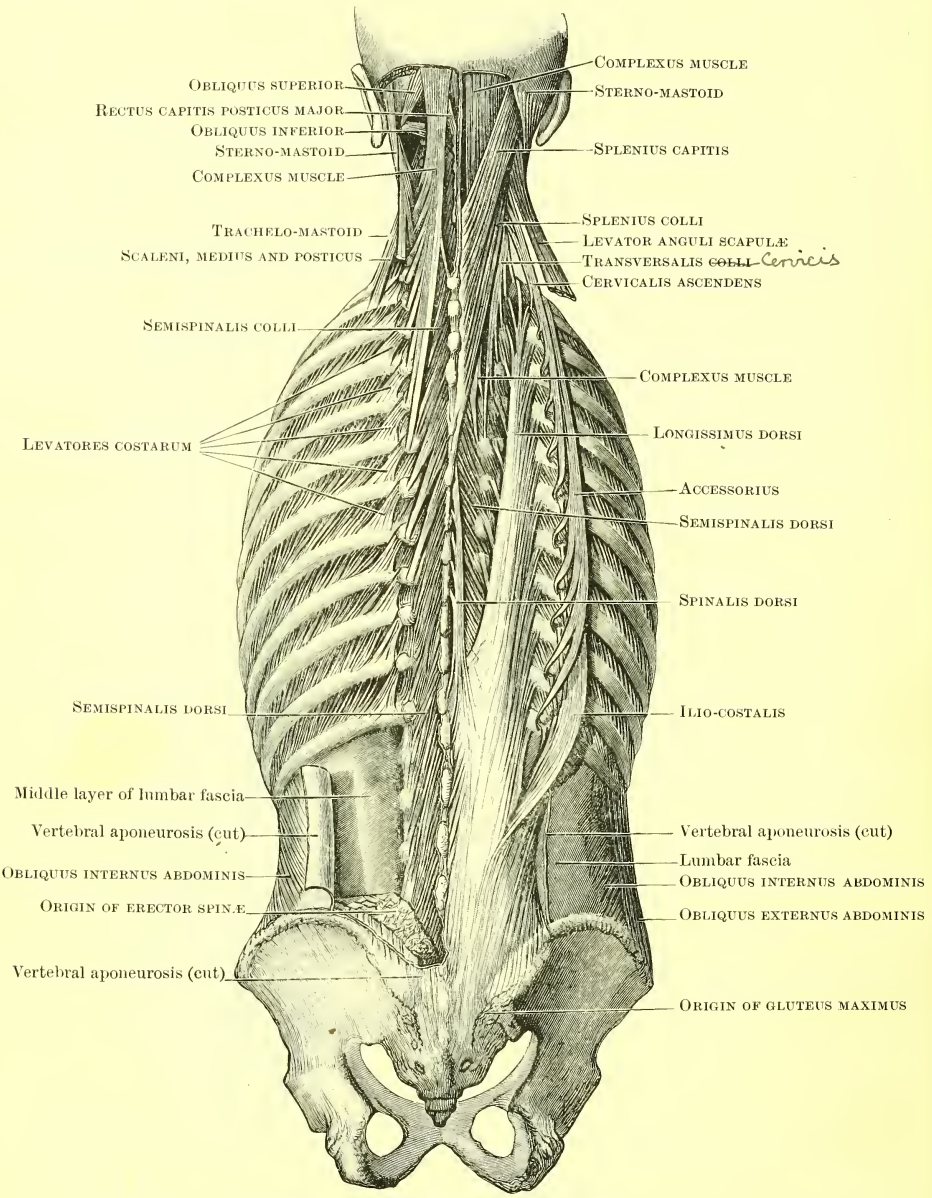


Fig. 309.—Deeper Muscles of the Back.

ribs, and internally into the transverse processes of the thoracic and the accessory processes of the upper lumbar vertebræ. It is prolonged upwards into the neck by its association with the common origin of two muscles, the transversalis cervicis and the trachelo-mastoid.

The **transversalis cervicis** (m. longissimus cervicis) has an **origin** from the transverse processes of the upper six thoracic vertebræ, internal to the insertions of the longissimus dorsi. Extending upwards into the neck, it is **inserted** into the

posterior tubercles of the transverse processes of the second, third, fourth, fifth, and sixth cervical vertebræ. It lies in the neck, underneath the cervicalis ascendens and splenius colli muscles.

The **trachelo-mastoid** (m. longissimus capitis) **arises**, partly by an origin common to it and the previous muscle, from the transverse processes of the upper six thoracic vertebræ, and partly by an additional origin from the articular processes of the lower four cervical vertebræ. Separating from the transversalis cervicis, the muscle ascends through the neck as a narrow band which is **inserted** into the mastoid process beneath the splenius capitis muscle. In the neck the muscle is placed between the splenius capitis and complexus.

The **spinalis dorsi** forms the innermost column of the erector spinæ. It occupies the thoracic portion of the back, and **arises** by tendinous fibres from the lower two thoracic and upper two lumbar spinous processes, and also directly from the tendon of the longissimus dorsi. It is a narrow muscle which, lying close to the thoracic spinous processes internal to the longissimus dorsi and complexus, is **inserted** into the upper (four to eight) thoracic spines. This muscle is not prolonged into the neck. It partially covers the semispinalis, dorsi, and colli.

The erector spinæ muscle is bound down by the vertebral aponeurosis, and is concealed by the more superficial muscles (sterno-mastoid, trapezius, levator anguli scapulæ, rhomboids, splenius, serrati postici). It covers the ribs posteriorly, and partially conceals the semispinales and complexus muscles.

The **complexus muscle** (m. semispinalis capitis) closely resembles in position and attachments the trachelo-mastoid. It takes **origin** by tendinous slips from the transverse processes of the upper six thoracic and the articular processes of the lower four cervical vertebræ, internal to the transversalis cervicis and trachelo-mastoid. It has an additional origin also from the spinous process of the last cervical vertebra. It forms a broad muscular sheet which extends upwards in the neck, to be **inserted** by fleshy and short tendinous fibres into the inner impression between the superior and inferior curved lines of the occipital bone (Fig. 312, p. 397). The inner portion of the muscle is separate, and forms the **biventer cervicis**, consisting of two fleshy bellies with an intervening tendon, placed vertically in contact with the ligamentum nuchæ. The insertion of the muscle is crossed by the occipital artery. The complexus is covered mainly by the splenius and trachelo-mastoid muscles. It conceals the semispinalis colli and the muscles of the suboccipital triangle, along with the accompanying vessels and nerves.

Third Group.

This group comprises the semispinales and multifidus spinæ.

These muscles are only incompletely separate from one another. The semispinales, dorsi, and colli, form a superficial stratum, the multifidus spinæ being more deeply placed. The more superficial muscles have the longer fibres; the fibres of the multifidus spinæ pass over fewer vertebræ. Both muscles extend obliquely upwards from transverse to spinous processes.

The **semispinalis muscle** extends from the loin to the axis vertebra. Its fibres are artificially separated into an inferior part, the **semispinalis dorsi**, and a superior part, the **semispinalis colli**.

The **semispinalis dorsi arises** from the transverse processes of the lower six thoracic vertebræ. It is **inserted** into the spinous processes of the last two cervical and first four thoracic vertebræ.

The **semispinalis colli** or **cervicis arises** from the transverse processes of the upper six thoracic vertebræ and the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the cervical vertebræ from the second to the fifth. The semispinalis muscle occupies the vertebral furrow, and is concealed by the erector spinæ and complexus; it covers the multifidus spinæ muscle. It is on the same plane as the muscles of the suboccipital triangle.

The **multifidus spinæ** differs from the previous muscle in extending from the sacrum to the axis, and in the shortness of its fasciculi, which pass over fewer vertebræ to reach their insertion. It **arises** from the sacrum, from the posterior

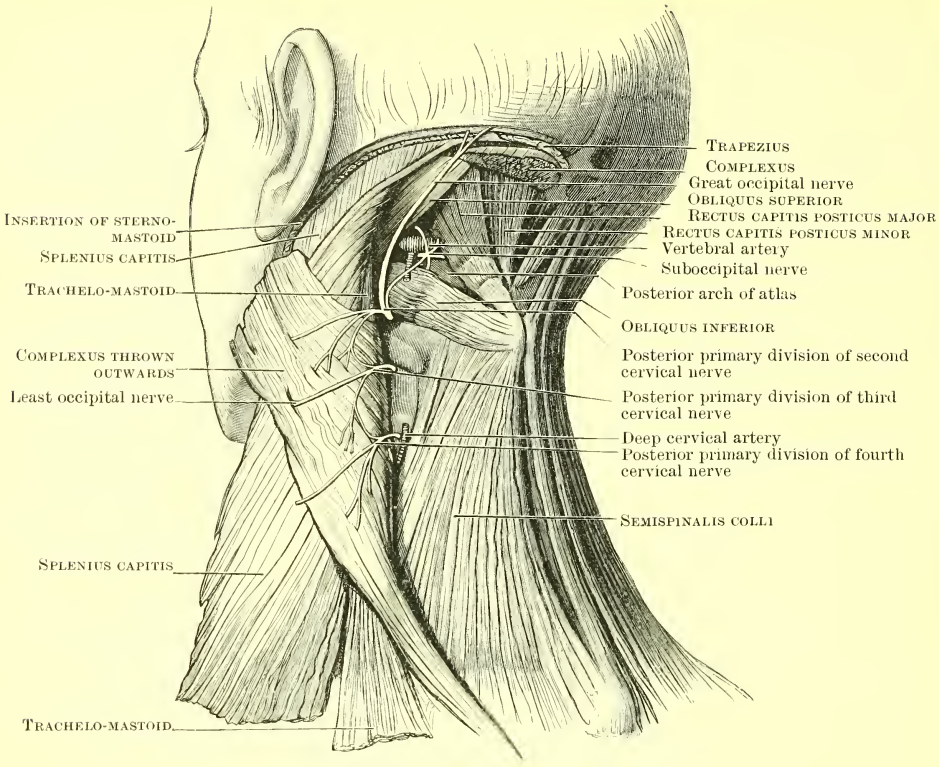


Fig. 310.—The Suboccipital Triangle.

sacro-iliac ligament (Fig. 311, p. 396), from the mammillary processes of the

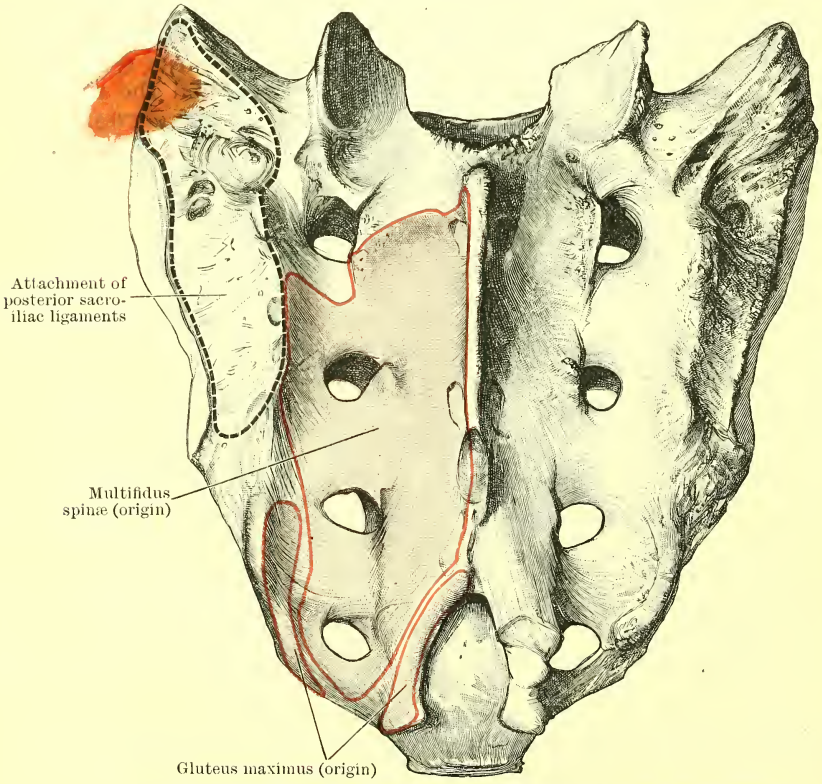


Fig. 311.—Muscle-Attachments to the Sacrum (Posterior Aspect).

lumbar vertebræ, from the transverse processes of the thoracic vertebræ, and from the articular processes of the lower four cervical vertebræ. It is **inserted** into the spines of the vertebræ up to and including the axis. Lying in contact with the vertebral laminæ, the muscle is covered in the back and neck by the semispinalis, and in the loin by the erector spinæ muscle.

Fourth Group.

This group includes several sets of small muscles, which are vertebro-cranial or inter-vertebral in their attachments.

The muscles bounding the **suboccipital triangle** are four in number—obliquus inferior, obliquus superior, rectus capitis posticus major, and rectus capitis posticus minor.

These muscles are concealed by the complexus and splenius capitis; they enclose a triangular space (the suboccipital triangle) in which the vertebral artery, the posterior primary division of the suboccipital nerve, and the posterior arch of

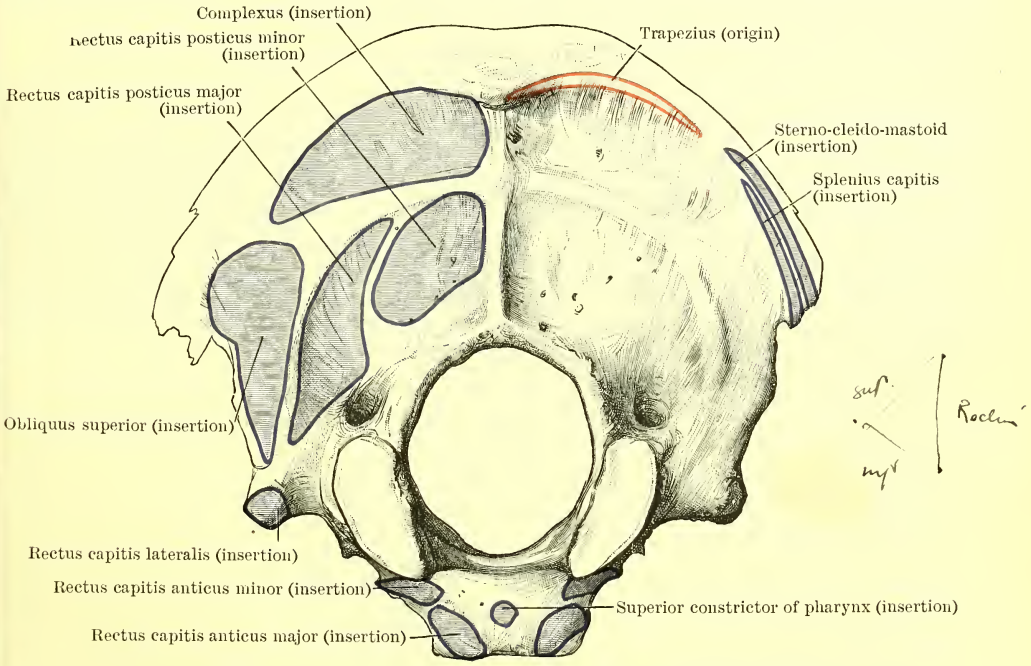


Fig. 312.—Muscle-Attachments to Occipital Bone (Inferior Surface).

the atlas are contained. The obliquus inferior is separated from the semispinalis muscle by the great occipital (second cervical) nerve.

The **obliquus inferior arises** from the spine of the axis, and is **inserted** into the transverse process of the atlas.

The **obliquus superior arises** from the transverse process of the atlas, and is **inserted** into the occipital bone beneath and external to the complexus and above the inferior curved line (Fig. 312, p. 397).

The **rectus capitis posticus major arises** from the spine of the axis, and is **inserted** into the occipital bone beneath the obliquus superior and complexus, and below the inferior curved line (Fig. 312, p. 397).

The **rectus capitis posticus minor arises** beneath the previous muscle from the spine of the atlas, and is **inserted** into the occipital bone below the inferior curved line internal to and beneath the rectus capitis posticus major (Fig. 312, p. 397).

The **rotatores dorsi** are eleven pairs of small muscles occupying the vertebral groove in the thoracic region, beneath the transverso-spinales, of which they form the deepest fibres. Each consists of a small slip **arising** from the transverse process, and **inserted** into the lamina of the vertebra directly above.

The **inter-spinales** are bands of muscular fibres connecting together the spinous processes of the vertebræ.

The **inter-transversales** are slender slips extending between the transverse processes. They are double in the neck, the anterior divisions of the spinal nerves passing between them.

The **rectus capitis lateralis**, extending from the transverse process of the atlas to the jugular process of the occipital bone (Fig. 312, p. 397), is homologous with the posterior of the two inter-transverse muscles. In the loin the inter-transversales muscles are usually double, but they are often absent, or are replaced by membrane.

Nerve-Supply.

With the exception of the vertebro-scapular and vertebro-humeral muscles (trapezius, latissimus dorsi, levator anguli scapulæ, rhomboidei, p. 318), the muscles of the back are all supplied by the *posterior primary divisions* of the spinal nerves. In the upper part of the trunk the muscles are supplied mainly by the external branches; in the lower part chiefly by the internal branches of the nerves. In the cervical and sacral regions a limited plexiform arrangement of the nerves occurs (*posterior cervical* and *posterior sacral plexuses*).

Actions.

The action of these muscles is extremely complex. Not only do they act on the spinal column, ribs, head, and pelvis, in conjunction with other muscles, but some of them act also in relation to the movements of the limbs as well. In this section will be given an analysis of their movements in relation to the spinal column, head, and pelvis. The movements of the limbs and of the ribs (respiration) are dealt with in other sections. The chief muscles are engaged in preserving the erect position, and in the movements of the trunk they are assisted in large measure by muscles whose chief movements are referred to elsewhere.

1. Movements of the Spinal Column.—The movements of the vertebral column are flexion, extension, and lateral movement or rotation. These movements occur in all regions—neck, thorax, and loin; flexion and extension and lateral movement are most limited in the region of the thorax; while rotation is most limited in the region of the loin.

a. **Flexion** and **Extension.**

Longus colli	Serrati postici
Rectus capitis anticus major	Splenius capitis
Scaleni antici (together)	Splenius colli
Psoas magnus and parvus	Erector spinæ
Levator ani	Semispinalis dorsi
Ischio-coccygeus	Semispinalis colli
	Complexus
Sphincter ani externus	Multifidus spinæ
Rectus abdominis	Interspinales
Pyramidalis abdominis	
Obliquus externus abdominis	Intercostal muscles
Obliquus internus „	Diaphragm
Transversalis „	Triangularis sterni

b. **Lateral Movement (Rotation).**

Levator anguli scapulæ	Rectus capitis anticus major
Serrati postici	Scaleni, anticus, medius, posticus
Splenius colli	Psoas (magnus and parvus)
Erector spinæ	Quadratus lumborum
Complexus	Obliquus externus abdominis
Semispinalis	Obliquus internus „
Multifidus spinæ	Transversalis „
Rotatores dorsi	Rectus „
Inter-transversales	Pyramidalis „
Longus colli	

2. Movements of the Head.—The movements of the head are flexion and extension, at the occipito-atlantoid articulation; lateral movement and rotation at the atlanto-axial joint.

a. **Flexion** and **Extension.**	
Digastric	Sterno-mastoid
Stylo-hyoid	Splenius capitis
Stylo-pharyngeus	Trachelo-mastoid
Mylo-hyoid	Complexus
Hyo-glossus	Obliquus inferior
Sterno-hyoid	Recti capitis postici (major and minor)
Sterno-thyroid	
Omo-hyoid	
Recti capitis antici (major and minor)	
(*the muscles of both sides acting together*)	

b. **Lateral Movement.**	*c.* **Rotation.**
Sterno-mastoid	Sterno-mastoid
Splenius capitis	Splenius capitis
Trachelo-mastoid	Trachelo-mastoid
Complexus	Complexus
Obliquus superior	Obliquus inferior
Rectus capitis lateralis	„ superior
	Recti capitis postici (major and minor)

Movements of the Pelvis.—The movements of the pelvis (as in locomotion) are partly caused by certain of the muscles of the back. Those muscles, which are attached to the spinal column or the ribs on the one hand, and to the innominate bone on the other, produce the movements (flexion, extension, and lateral movement) of the whole pelvis. In addition, the muscles passing between the innominate bone and femur, in certain positions of the lower limb, assist in these movements.

a. **Extension** and **Flexion.**	
Latissimus dorsi	Psoas magnus and parvus
Erector spinæ	Rectus abdominis
Multifidus spinæ (acting on both sides)	Pyramidalis abdominis
	Obliquus externus abdominis
	Obliquus internus „
	Transversalis abdominis (acting on both sides)
	Pyriformis
	Glutei
	Obturator (externus and internus)
	Sartorius
	Tensor fasciæ femoris
	Iliacus
	Rectus femoris
	Adductors (in the erect position)
b. **Lateral Movement.**	
Flexors and extensors of side only	Quadratus lumborum

THE FASCIÆ AND MUSCLES OF THE HEAD AND NECK.

FASCIÆ.

The **superficial fascia** of the head and neck possesses certain features of special interest. Over the scalp it is closely adherent to the skin and subjacent epicranial aponeurosis, and contains the superficial vessels and nerves. Beneath the skin of the eyelids it is loose and thin and contains no fat. Over the face and at the side of the neck it is separated from the deep fascia by the facial muscles and the platysma myoides. In the hollow between the buccinator and the masseter it is continuous with a pad of fat (*suctorial pad*) occupying the interval between these muscles.

The **deep fascia** of the head and neck presents many remarkable characters. *Over the scalp* it is represented by the **epicranial aponeurosis,** the tendon of the occipito-frontalis muscle. This is a tough membrane, tightly stretched over the calvarium, from which it is separated by loose areolar tissue. It is attached posteriorly, partly through the agency of the occipitalis muscle, to the superior curved line of the occipital bone; anteriorly it joins the frontalis muscle and the orbicularis palpebrarum, and has no bony attachment; laterally it is attached to the temporal ridge and the mastoid process. Below the temporal ridge it is continuous with the **temporal fascia,** a stout layer of fascia attached to the temporal ridge and zygomatic arch, which covers and gives origin to the temporal muscle. This fascia separates into two layers above the zygoma, to enclose a quantity of fat along with branches of the temporal and orbital arteries. On the face the fascia is practically non-existent anteriorly in relation to the facial muscles. Posteriorly it forms the thin **masseteric fascia**, and is much thicker in relation to the parotid gland, for which it forms a capsule.

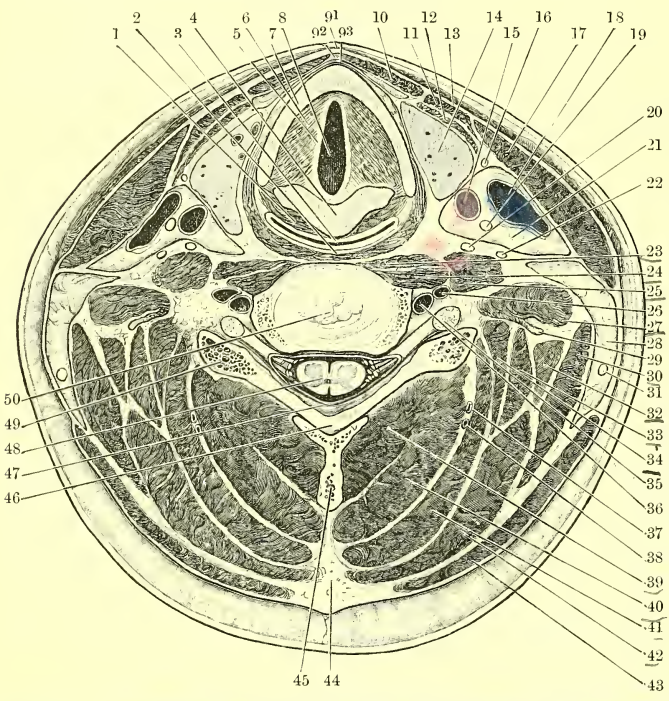


Fig. 313.—Transverse Section in the Cervical Region (between the fourth and fifth cervical vertebræ).

1. Crico-thyroid muscle.
2. Inferior constrictor muscle.
3. Pharynx.
4. Cricoid cartilage.
5. Vocal cord.
6. Thyro-arytenoid muscle.
7. Thyroid cartilage.
8. Glottis.
9. Layers of deep cervical fascia.
10. Sterno-hyoid muscle.
11. Omohyoid muscle.
12. Sterno-thyroid muscle.
13. Cervical fascia.
14. Thyroid body.
15. Common carotid artery.
16. Descendens hypoglossi nerve.
17. Sterno-mastoid muscle.
18. Internal jugular vein.
19. Pneumogastric nerve.
20. Sympathetic nerve.
21. Carotid sheath.
22. Phrenic nerve.
23. Longus colli muscle.
24. Rectus capitis anticus major.
25. Scalenus anticus.
26. Vertebral vein.
27. Scalenus medius.
28. Posterior triangle.
29. Scalenus posticus.
30. Levator anguli scapulæ.
31. Spinal accessory nerve.
32. Splenius colli.
33. Transversalis crevicis.
34. Trachelo-mastoid.
35. Spinal nerve.
36. Vertebral artery.
37. Profunda cervicis vein.
38. Profunda cervicis artery.
39. Multifidus spinæ.
40. Semispinalis colli.
41. Complexus.
42. Splenius capitis.
43. Trapezius.
44. Ligamentum nuchæ
45. Spine of fourth cervical vertebra.
46. Lamina of fifth cervical vertebra.
47. Dura mater.
48. Spinal cord.
49. Transverse process.
50. Disc between fourth and fifth cervical vertebræ.

In the neck the deep fascia invests the muscles, and forms aponeurotic coverings for the pharynx, trachea, œsophagus, glands, and large vessels. It encloses the sterno-mastoid muscle, and can be traced backwards over the posterior triangle to the trapezius and deeper muscles, which it surrounds; it can be traced forwards over the anterior triangle to the middle line of the neck, where it forms a continuous membrane. *Above the sternum* the fascia, after enclosing the sterno-mastoid muscles, is attached in the form of two layers to the front and back of the episternal notch. The layer enclosing the infrahyoid muscles passes across the middle line of the neck in front of the trachea, and is attached above to the hyoid bone, below to the sternum, clavicle, and first rib. A third layer of fascia passes inwards in front of the trachea, enclosing the thyroid body. Beneath the sterno-mastoid the fascia helps to form the **carotid sheath**, which is completed by septal processes stretching inwards across the neck in relation to the infrahyoid muscles, trachea, œsophagus, and pharynx, and the prevertebral muscles. The trachea,

œsophagus, and pharynx, are likewise encapsuled in cervical fascia, a septal layer passing across the middle line of the neck between the trachea and œsophagus. Lastly, a strong **prævertebral fascia** passes across the neck in front of the prævertebral muscles, and behind the œsophagus and pharynx.

The cervical fascia is attached above to the **bones of the skull**: superficially to the superior curved line of the occipital bone, the mastoid process, the zygoma (over the parotid gland), and the lower border of the mandible; more deeply to the styloid and vaginal processes of the temporal bone, the great wing of the sphenoid and the basilar process. This deeper attachment (*prævertebral fascia*) is behind the parotid gland and pharynx, and is associated with the formation of three ligaments: **stylo-mandibular ligament, internal lateral ligament** of the lower jaw, and **pterygo-spinous ligament.** The fascia is attached below, through its muscular connexions, to the sternum, first rib, clavicle, and scapula. By means of its connexion with the trachea and the common carotid artery it is carried down behind the first rib into the superior mediastinum, and so becomes continuous with the pericardium. By means of its connexion with the subclavian vessels and brachial nerves it is carried down to the axilla, as the subclavian sheath, which becomes connected with the costo-coracoid membrane.

THE MUSCLES OF THE HEAD.

The muscles of the head are divisible into three separate groups with very different relations and uses—viz., superficial muscles, muscles of the orbit, and muscles of mastication.

Superficial Muscles.

The superficial muscles comprise a large group, including the muscles of the scalp and face, and the platysma myoides in the neck.

The **platysma myoides** is a thin quadrilateral sheet extending from chest to face over the side of the neck, between the superficial and deep fasciæ. It **arises** from the deep fascia of the pectoral region and the clavicle. It is directed upwards and forwards, and is partly **inserted** (by its intermediate fibres) into the lower border of the mandible, becoming connected with the depressor labii inferioris and depressor anguli oris muscles (Fig. 319, p. 407). The more anterior fibres pass across the middle line of the neck and decussate for a variable distance below the chin with those of the opposite side. The posterior fibres sweep over the angle of the jaw and become continuous with the risorius muscle. The platysma myoides is the rudiment of the cervical portion of the **panniculus carnosus** of lower animals, in which it has a much more intimate connexion with the muscles of the face than is usually the case in man.

The Muscles of the Scalp.

The muscles of the scalp comprise the muscles of the external ear and the occipito-frontalis muscle.

The **occipito-frontalis** is a muscle with two bellies and an intervening tendon (the epicranial aponeurosis) which stretches uninterruptedly across the middle line of the cranium. The **posterior belly** (occipitalis) **arises** as a broad flat band from the outer two-thirds of the superior curved line of the occipital bone. The **anterior belly** (frontalis) has no bony attachments; **arising** from the epicranial aponeurosis about the level of the coronal suture, it passes downwards to the supra-orbital arch, where it blends with the orbicularis palpebrarum and corrugator supercilii muscles. It extends across the full width of the forehead, and blends in the middle line with the muscle of the opposite side.

The **epicranial aponeurosis,** extending between the two fleshy bellies, is a continuous membrane which glides over the calvarium, and has attachments laterally to the temporal ridge, and behind, between the posterior bellies, to the superior curved line of the occipital bone. It has no osseous attachment anteriorly. The occipito-frontalis is usually rudimentary. By the contraction of the fibres of the frontalis muscle the skin of the forehead is thrown into horizontal parallel folds.

The **extrinsic muscles of the ear** are three in number: retrahens, attollens, and attrahens aurem.

The **retrahens aurem** (m. auricularis posterior) is a narrow fleshy slip which **arises** from the surface of the mastoid process and is **inserted** into the deep surface of the pinna. It bridges across the groove between the mastoid process and the pinna, and conceals the posterior auricular vessels and nerve.

The **attollens aurem** (m. auricularis superior) is a small fan-shaped muscle which **arises** from the temporal fascia, and descends to be **inserted** into the top of the root of the pinna.

The **attrahens aurem** (m. auricularis anterior) is a similar small muscle, placed in front of the attollens, and stretching obliquely between the temporal fascia and the top of the root of the pinna.

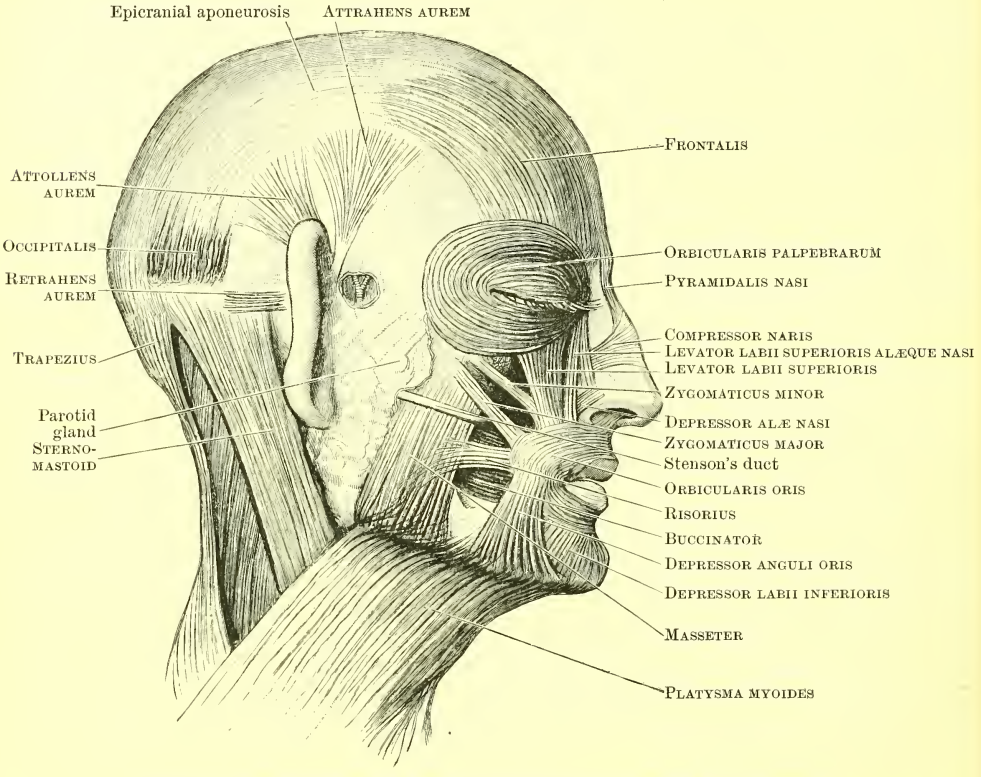


Fig. 314.—The Muscles of the Face and Scalp (muscles of expression).

These two muscles conceal branches of the temporal vessels as they lie on the temporal fascia.

The ear muscles are rudimentary and usually functionless.

The Muscles of the Face.

The facial muscles are divided into three groups, associated with the several apertures of the eye, nose, and mouth.

1. The **muscles of the eyelids** include four muscles: the levator palpebræ superioris (described with the orbital muscles), orbicularis palpebrarum, tensor tarsi, and corrugator supercilii.

The **orbicularis palpebrarum** (m. orbicularis oculi) is a transversely oval sphincter muscle surrounding and occupying the eyelids. It is divisible into an *external portion* (pars orbitalis) composed of coarse fibres, spreading on to the forehead, temple, and cheek, and an *internal portion* (pars palpebralis), composed of finer fibres, situated beneath the skin of the eyelids. At the inner canthus of the eye the muscle (by its palpebral fibres) gains an **attachment** to the tarsal ligament

and the borders of the naso-lachrymal groove. Its fibres enclose the lachrymal sac and the canaliculi. The posterior fibres, extending between the posterior edge of the naso-lachrymal groove and the tarsal ligaments behind the lachrymal sac, constitute the **tensor tarsi muscle.** The fibres of the muscle which extend along the margins of the lids constitute a separate **ciliary bundle.**

Externally the orbicularis palpebrarum has no bony attachment; so that when it contracts and closes the eyelids, both lids at the same time tend to be drawn inwards towards the inner canthus of the eye.

The **corrugator supercilii arises** from the nasal eminence, and passing horizontally outwards, blends with the upper fibres of the orbicularis palpebrarum on its under surface. The contraction of this muscle throws the skin of the forehead into vertical folds, while at the same time drawing the inner half of the eyebrow upwards, it produces concentric curved folds on each side of the middle line of the forehead.

2. The **muscles of the nose** comprise five small muscles proper to the nose, and one common to the nose and upper lip: the pyramidalis nasi, compressor naris. dilatores naris (anterior and posterior), depressor alæ nasi, and levator labii superioris alæque nasi. They are all small and feeble.

The **pyramidalis nasi arises** from the occipito-frontalis muscle and the skin over the glabella; it is **inserted** into a membrane stretching over the nose, which also gives attachment to the compressor naris.

The **compressor naris** (m. nasalis) **arises** by a narrow origin from the superior maxilla, under cover of the levator labii superioris alæque nasi. It passes forwards over the bridge of the nose, and ends in a membranous **insertion** common to it and the previous muscle.

The **dilatores naris** are feeble muscular slips placed on the outer side of the margin of the nostril, one anteriorly, the other posteriorly.

The **depressor alæ nasi** is a small muscle **arising** from the upper part of the incisor fossa of the maxilla; it divides into two parts as it passes upwards and inwards, and is **inserted** into the ala and the septum of the nose (depressor septi).

The **levator labii inferioris alæque nasi** is a narrow band **arising** from the root of the nasal process of the maxilla. It descends alongside the nose, and is **inserted** partly into the ala of the nose and partly into the orbicularis oris muscle.

3. The **muscles of the mouth** comprise eleven muscles, of which all but one, the orbicularis oris, are bilaterally placed. The muscles are: levator labii superioris alæque nasi, levator labii superioris, levator anguli oris, zygomatici (major and minor), risorius, orbicularis oris, depressor anguli oris, depressor labii inferioris, levator menti, and buccinator.

The **orbicularis oris** is the sphincter muscle surrounding the lips. It is continuous with the other muscles converging to the mouth. It lies between the skin and mucous membrane of the mouth, and is limited above by the nose, below by the junction of lower lip and chin. Its mesial fibres are attached above to the septum of the nose (naso-labial band) and to the incisor fossa (superior incisive bundle); below they are attached to the lower jaw on each side of the symphysis (inferior incisive bundle). These bundles radiate outwards to join the rest of the muscle, which is joined at its margin by the levators and depressors of the lower lip and angle of the mouth, and by the buccinator muscle. The *lower fibres* of the muscle are continued laterally into the buccinator and levator anguli oris; its *upper fibres* are continued into the buccinator and depressor anguli oris.

The **levator labii superioris alæque nasi** has already been described.

The **levator labii superioris arises** from the superior maxilla just above the infra-orbital foramen. It passes almost vertically downwards to join the orbicularis oris and the skin of the upper lip between the attachments of the levator labii superioris alæque nasi and the levator anguli oris. It conceals the infra-orbital vessels and nerve.

The **levator anguli oris arises** from the canine fossa of the upper jaw below the infra-orbital foramen and under cover of the foregoing muscle. It is directed outwards and downwards, to be **inserted** into the orbicularis oris and the skin at the angle of the mouth.

The **zygomatici** (**major** and **minor**) are more superficial than the preceding muscle.

The **zygomaticus minor** is the anterior muscle. It **arises** from the malar bone, and is often continuous with the most peripheral fibres of the orbicularis palpebrarum. It is directed obliquely downwards and forwards over the levator anguli oris, to be **inserted**, along with the levator labii superioris, into the orbicularis oris. The **zygomaticus major** is a narrow muscular band which **arises** from the malar portion of the zygomatic arch. It passes to the angle of the mouth, to be **inserted** partly into the skin, partly into the orbicularis oris.

The **risorius** is a thin flat muscle which forms in part a continuation of the platysma myoides on the face, in part a separate muscle, with an **origin** from the masseteric fascia. It passes transversely forwards, to be **inserted** at the angle of the mouth into the orbicularis oris and skin.

The **depressor anguli oris arises** from the external oblique line of the lower jaw and from the platysma myoides (Fig. 319, p. 407). It is triangular in form, its fibres converging to the angle of the mouth, where they are **inserted** into the orbicularis oris and the skin. Some of the fibres reach the upper lip through the orbicularis muscle.

The **depressor labii inferioris arises** from the outer surface of the lower jaw beneath and internal to the depressor anguli oris (Fig. 319, p. 407). It is quadrilateral in form, and is directed upwards, to be **inserted** into the orbicularis oris and the skin of the lower lip. Its external fibres conceal the mental foramen, and are overlapped by the depressor anguli oris. Its internal fibres join with those of the opposite muscle.

The **levator menti** is a small muscle which **arises** from the incisor fossa of the lower jaw (Fig. 319, p. 407), and passing forwards, is **inserted** into the skin of the chin.

The **buccinator muscle** forms the lateral wall of the mouth, and is in series posteriorly with the constrictor muscles of the pharynx. It **arises** (1) from the alveolar arches of the upper and lower jaws (Fig. 319, p. 407), and between these attachments, from the pterygo-mandibular ligament. Its fibres are directed forwards to the angle of the mouth, where they blend with the corresponding (upper and lower) portions of the orbicularis oris muscle. The *middle fibres* of the muscle decussate at the angle of the mouth, so as to pass, the lower set to the upper lip, the upper set to the lower lip. The buccinator is covered on its deep surface by the mucous membrane of the mouth. Superficially it is concealed by the muscles above mentioned, which converge to the angle of the mouth; it is separated from the masseter by the *suctorial pad of fat*; it is pierced by the duct of the parotid gland, and by branches of the long buccal nerve.

Nerve-Supply.

The facial and scalp muscles are all innervated by the **facial nerve.** The *posterior auricular branch* supplies the retrahens aurem and occipitalis; the branches forming the *pes anserinus* supply the frontalis, attollens, and attrahens aurem, the several muscles associated with the apertures of the eye, nose, and mouth (including the buccinator), and the platysma myoides.

Actions.

The almost infinite variety of facial expression is produced partly by the action of these muscles, partly by their inactivity, or by the action of antagonising muscles (antithesis). On the one hand joy is, for example, betrayed by the action of one set of muscles, while grief is accompanied by the contraction of another (opposing) set. Determination or eagerness is accompanied by a fixed expression due to a combination of muscles acting together; despair, on the other hand, is expressed by a relaxation of muscular action. For a philosophical account of the action of the facial muscles, the student should consult Darwin's *Expression of the Emotions in Man and Animals*, and Duchenne's *Mechanisme de la Physiologie humaine.*

The **platysma myoides** retracts and depresses the angle of the mouth, and depresses the lowe jaw. The **occipito-frontalis**, by its anterior belly, raises the eyebrows; both bellies acting together tighten the skin of the scalp; acting along with the orbicularis palpebrarum, it shifts the scalp backwards and forwards. The **corrugator supercilii** draws inwards the eyebrow and vertically wrinkles the skin of the forehead. The **pyramidalis nasi** draws downwards the skin between the eyebrows, as in frowning. The upper eyelid is raised by the **levator palpebræ superioris.** The closure of the lids is effected by the **orbicularis palpebrarum,** whose fibres also

assist in the lowering of the eyebrows, in the protection of the eyeball, and, by pressure on the lachrymal gland, in the secretion of tears. The **tensor tarsi**, acting along with the orbicularis palpebrarum, compresses the lachrymal sac and aids in the passage of its contents into the nasal duct. The **muscles of the ear** and **nose** have quite rudimentary actions expressed by their names. Of the muscles of the mouth, the **orbicularis oris** has a complex action, depending on the degree of contraction of its component parts. It causes compression and closure of the lips in various ways, tightening the lips over the teeth, contracting them as in osculation, or causing pouting or protrusion of one or the other. The **accessory muscles** of the **lips** draw them upwards (zygomatici, levator anguli oris, levator labii superioris alæque nasi, levator labii superioris), outwards (zygomaticus major, risorius, platysma, depressor anguli oris, buccinator), and downwards (depressor anguli oris, depressor labii inferioris, platysma). The **levator menti** elevates the skin of the chin and protrudes the lower lip. The **buccinator** retracts the angles of the mouth, flattens the cheeks, and brings them in contact with the teeth.

The Fascia and Muscles of the Orbit.

The eyeball with its muscles, vessels, and nerves, is lodged in a mass of soft and yielding fat which entirely fills up the cavity of the orbit. Surrounding the posterior part of the eyeball is the **capsule of Tenon**, which constitutes a large lymph space or synovial bursa in relation to the eyeball. Anteriorly the capsule is in contact with the conjunctiva, and intervenes between the latter and the eyeball; posteriorly it is pierced by and prolonged along the optic nerve. It is a smooth membrane connected to the globe of the eye by loose areolar tissue. It is pierced by the tendons of the ocular muscles, along which it sends prolongations continuous with the muscular sheaths.

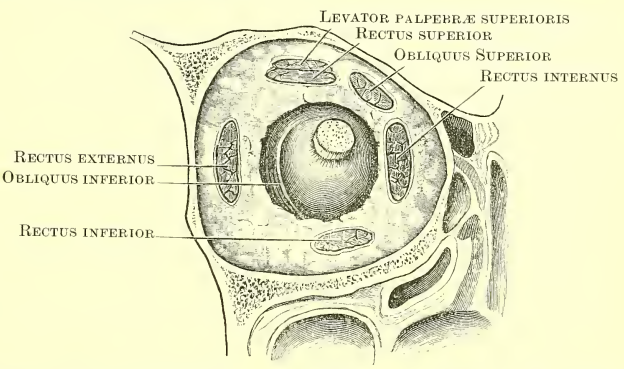


Fig. 315.—Transverse Vertical Section through the Orbit behind the Eyeball to show the Arrangement of Muscles.

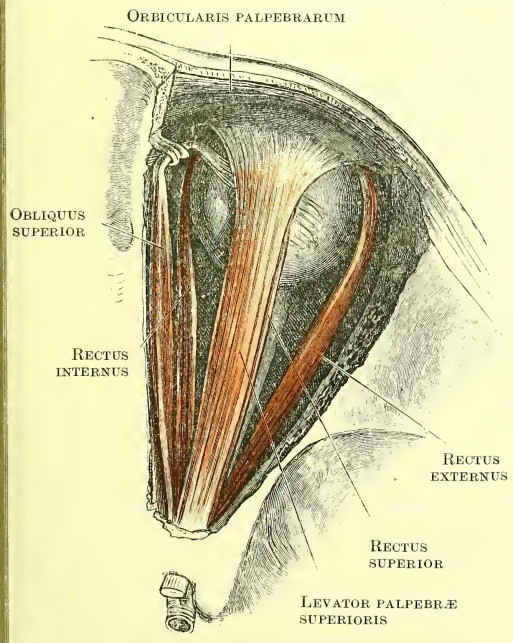


Fig. 316.—The Muscles of the Orbit (from above).

The **muscles of the orbit** are seven in number: one, the levator palpebræ superioris, belongs to the upper eyelid; the other six are muscles of the eyeball.

The **levator palpebræ superioris** lies immediately beneath the orbital periosteum and covers the superior rectus muscle. It has a narrow **origin** above that muscle from the margin of the optic foramen. It expands as it passes forwards, to end, in relation to the upper lid, in a membranous expansion which is **inserted** in a fourfold manner: (1) slightly into the orbicularis palpebrarum and skin of the upper lid, (2) mainly into the upper border of the tarsal cartilage, (3) slightly into the conjunctiva, and (4) by its edges into the upper border of the margin of the orbital opening.

The **recti muscles** are four in number—**superior**, **inferior**, **internal**, and **external**. They all **arise** from a membranous ring surrounding the optic foramen, which is separable into two parts—a *superior common tendon*, giving origin to the superior and internal

recti and the upper head of the external rectus; and an *inferior common tendon*, giving origin to the internal and inferior recti and the lower head of the external rectus. The two origins of the external rectus muscle are separated by the passage into the orbit of the oculo-motor, nasal, and abducent nerves. Forming flattened bands which traverse the fat of the orbit around the optic nerve and eyeball, the four muscles end in tendons which pierce the capsule of Tenon, and are **inserted** into the sclerotic about eight millimetres (~~three to four lines~~) behind the margin of the cornea. The **superior** and **inferior recti** are inserted in the vertical plane slightly internal to the axis of the eyeball; the **external** and **internal recti** in the transverse plane of the eyeball; and all are attached in front of the equator of the eyeball.

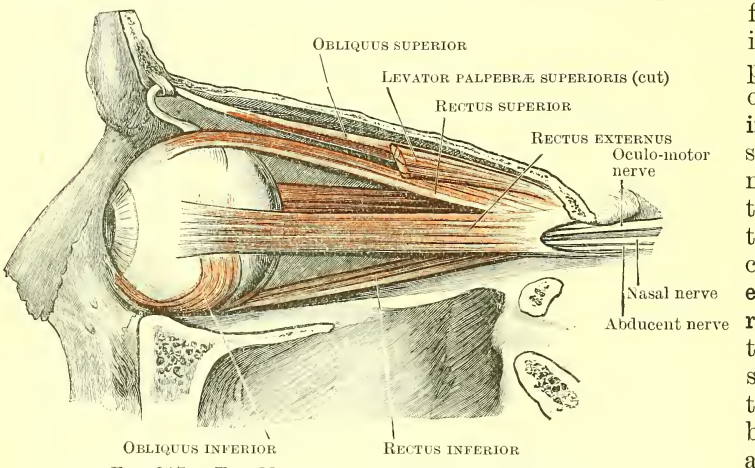


Fig. 317.—The Muscles of the Orbit (from without).

The **obliquus superior arises** from the margin of the optic foramen between the recti superior and internus. It passes forwards as a narrow muscular band internal to the rectus superior, and at the anterior margin of the orbit forms a narrow tendon which passes through a special fibrous pulley (trochlea) attached to the roof of the orbit. Its direction is then altered, and passing outwards

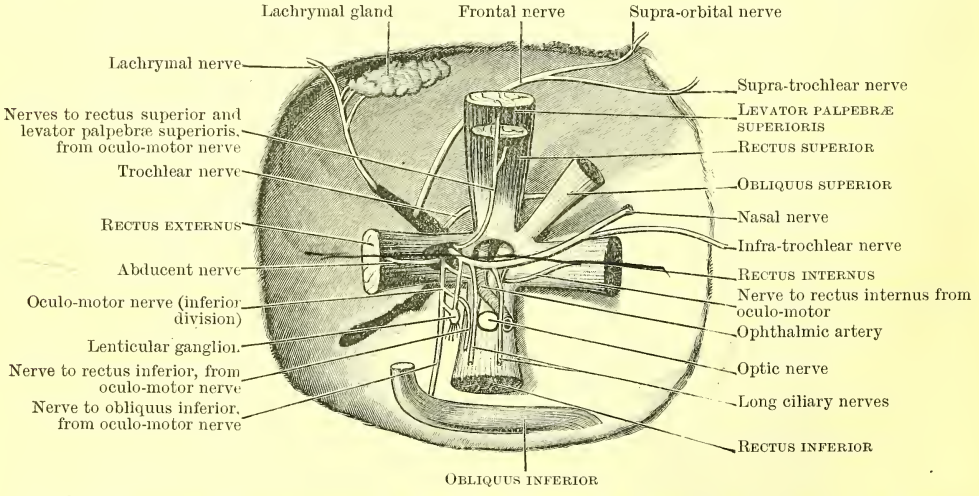


Fig. 318.—Schematic Representation of the Nerves which traverse the Cavity of the Orbit.

between the tendon of the superior rectus and the eyeball, it is **inserted** into the sclerotic between the superior and external recti, midway between the margin of the cornea and the entrance of the optic nerve.

The **obliquus inferior arises** from the inner side of the floor of the orbit just behind its anterior margin, and external to the naso-lachrymal groove. It forms a slender rounded slip, which curls round the inferior rectus tendon, and passes between the external rectus and the eyeball, to be **inserted** into the sclerotic between the superior and external recti, and farther back than the superior oblique muscle.

Müller's muscle is a rudimentary bundle of non-striated muscular fibres bridging across the

spheno-maxillary fissure and infra-orbital groove. It is supplied by fibres from the sympathetic, and may have a slight influence in the protrusion of the eyeball.

Nerve-Supply.

The muscles of the orbital cavity are supplied by the third, fourth, and sixth cranial nerves. The **fourth nerve** (trochlearis) supplies the obliquus superior; the **sixth** (abducens) supplies the rectus externus; the **third nerve** (motor oculi) supplies the others—levator palpebræ superioris, recti, superior, inferior and internus, and obliquus inferior.

Actions.

The **levator palpebræ superioris** elevates the upper eyelid and antagonises the orbicularis palpebrarum muscle. The six muscles inserted into the eyeball serve to move the longitudinal axis of the eyeball upwards, downwards, inwards, and outwards, besides causing a rotation of the eyeball on its own axis. The following table expresses the action of individual muscles. It must be remembered that, while similar movements occur simultaneously in the two eyeballs, the horizontal movements may, by adduction of the muscles of both sides, cause convergence of the axes of the two eyeballs for the purposes of near vision.

a. **Adduction** and **Abduction.**	
Rectus internus Rectus superior Rectus inferior	Rectus externus Obliquus superior (*correcting* Obliquus inferior *adductors*)
b. **Elevation** and **Depression.**	
Rectus superior Obliquus inferior	Rectus inferior Obliquus superior
c. **Rotation outwards.**	**Rotation inwards.**
Obliquus inferior	Obliquus superior Rectus superior Rectus inferior (*in adduction*)

Muscles of Mastication.

The muscles of mastication comprise the masseter, temporal, external and internal pterygoids, and buccinator (described above).

The **masseter** has an **origin** which is partly tendinous and partly fleshy. It arises in two parts: (1) superficially from the lower border of the zygoma in its anterior two-thirds. and (2) more deeply from the deep or inner surface of the zygoma in its whole length. The superficial fibres are directed downwards and backwards towards the angle of the jaw; the deeper fibres are directed vertically downwards. The muscle is **inserted** by fleshy and tendinous fibres into the outer surface of the ramus and angle of the lower jaw and the coronoid process (Fig. 319, p. 407). The deepest fibres blend with the fibres of the subjacent temporal muscle.

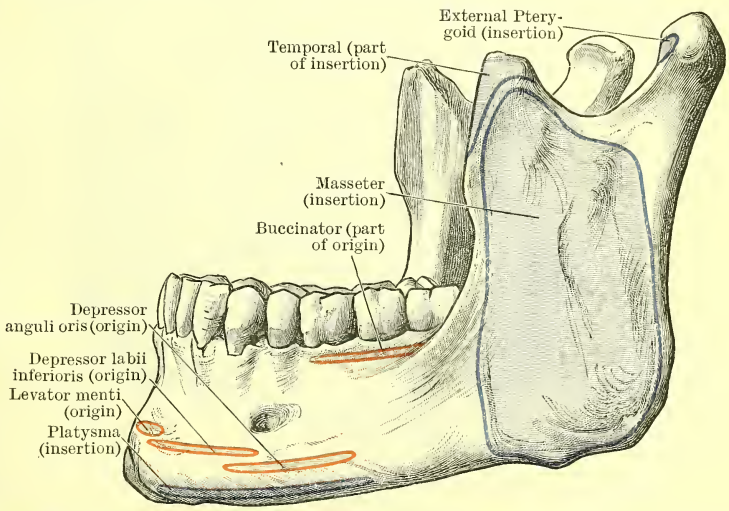


Fig. 319.—Muscle-Attachments to the Outer Aspect of the Lower Jaw.

The masseter muscle occupies the posterior part of the cheek. It is covered by the parotid gland, and is crossed by Stenson's duct and the branches of the

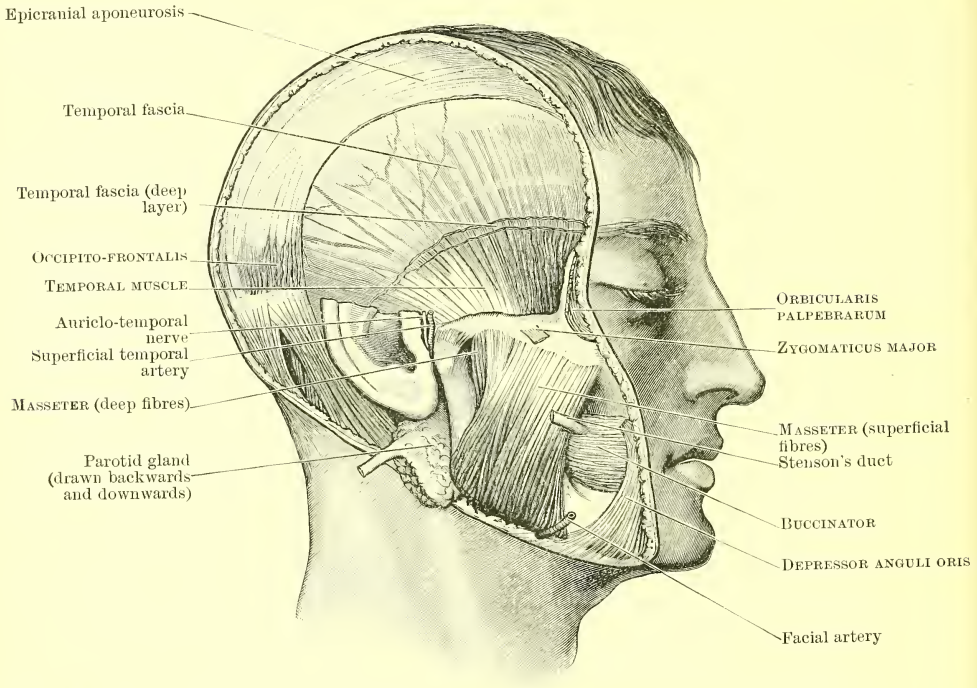


Fig. 320.—Muscles of Mastication (superficial view).

facial nerve. It conceals the lower jaw and a part of the temporal muscle, and is separated from the buccinator muscle anteriorly by a pad of fat.

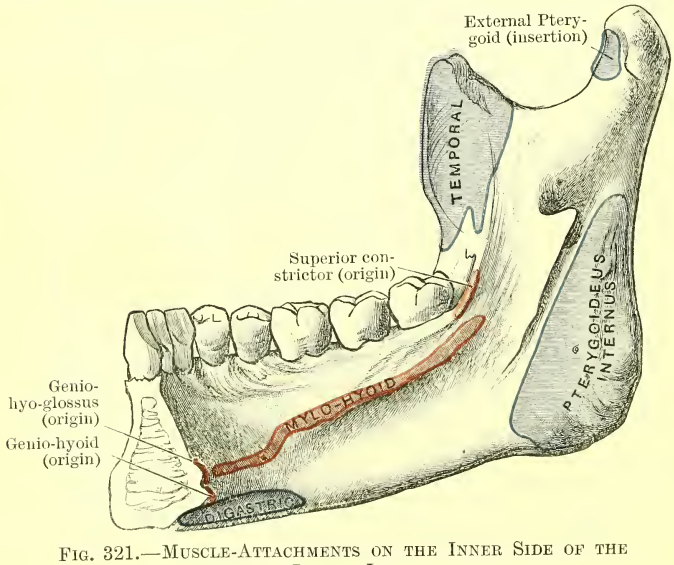


Fig. 321.—Muscle-Attachments on the Inner Side of the Lower Jaw.

The **temporal muscle** is a fan-shaped muscle **arising** from the whole area of the temporal fossa, as well as from the temporal fascia which covers it. Its converging fibres pass beneath the zygomatic arch. In the pterygoid region the muscle is **inserted** into the deep surface and apex of the coronoid process, and into the anterior border of the ramus of the lower jaw (Figs. 319, p. 407, and 321, p. 408).

The muscle is concealed by the temporal fascia, zygoma, the masseter muscle, and the coronoid process. It crosses over the external pterygoid muscle and the internal maxillary artery.

The **external pterygoid muscle** arises by two heads, upper and lower. The upper head is attached to the under surface of the great wing of the sphenoid; the lower head takes origin from the outer surface of the external pterygoid plate. The

muscle is directed outwards and backwards, to be **inserted** into (1) the depression in front of the neck of the lower jaw (Figs. 319, p. 407, and 321, p. 408), and (2) the inter-articular fibro-cartilage and capsule of the temporo-maxillary articulation.

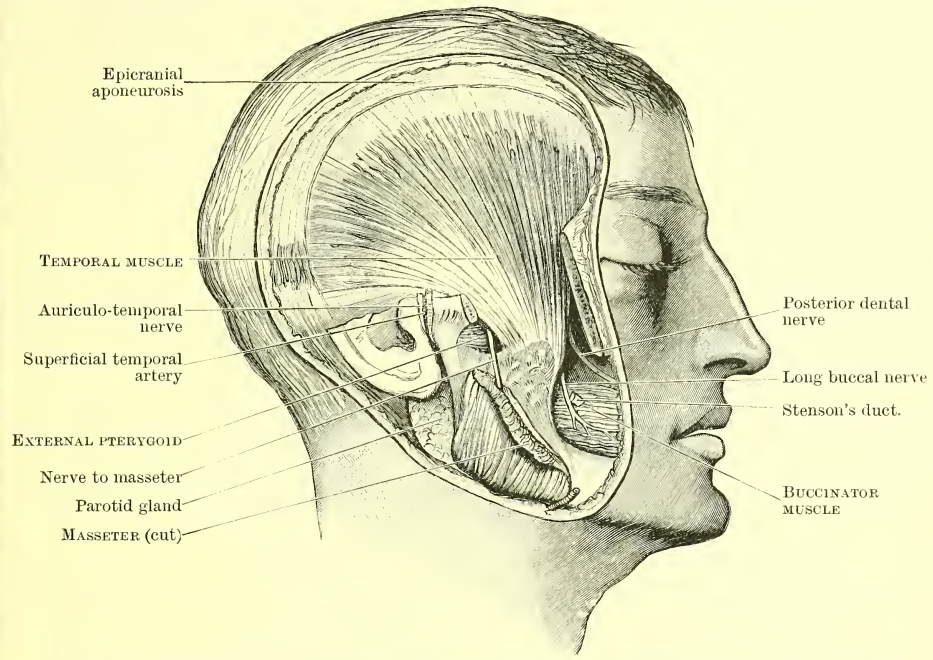


Fig. 322.—Muscles of Mastication, Deeper View (zygoma and masseter muscle removed).

The muscle is placed deeply in the pterygoid region. Covered by the temporal muscle and coronoid process, it partially conceals the internal pterygoid muscle

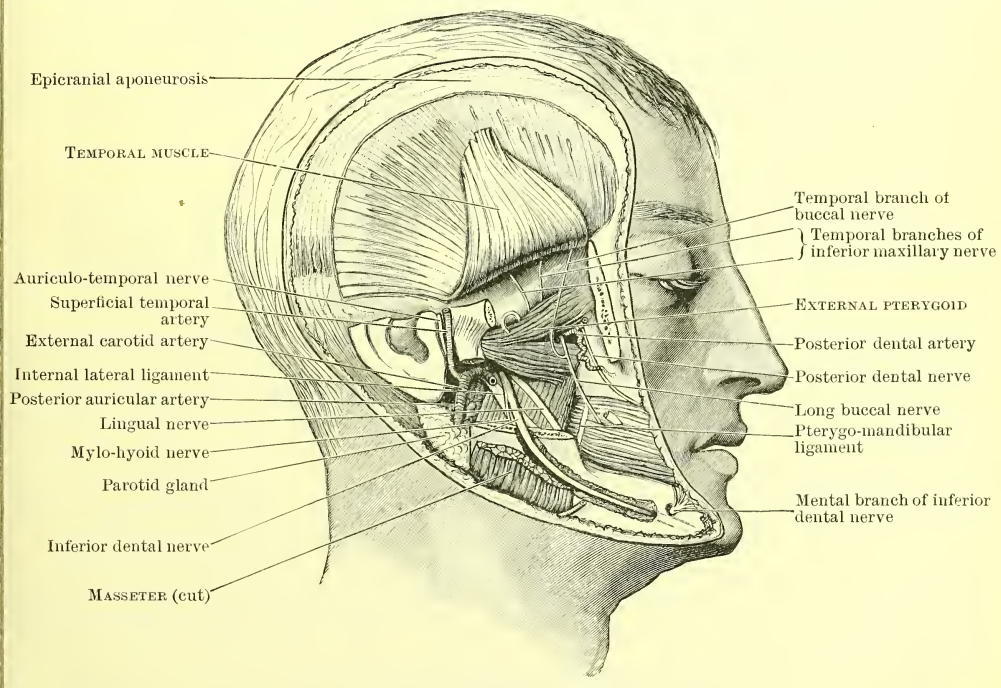


Fig. 323.—Pterygoid Region.

and the trunk and branches of the inferior maxillary nerve. The internal maxillary artery passes over or under the muscle, and disappears between its two heads of origin on its way to the spheno-maxillary fossa.

The **internal pterygoid muscle** has likewise a double **origin**—(1) from the deep surface of the external pterygoid plate and the tuberosity of the palate, and (2) by a stout tendon from the tuberosity of the upper jaw. Its two heads of origin embrace the lower fibres of the external pterygoid muscle. It is quadrilateral in form, and is directed downwards, outwards, and backwards, to be **inserted** into a triangular impression on the inner surface of the lower jaw, between the mylo-hyoid groove and the angle of the bone (Fig. 321, p. 408).

The muscle is covered over by the external pterygoid muscle, by branches of the inferior maxillary nerve, and by the internal lateral ligament and ramus of the lower jaw. Beneath it are the Eustachian tube, muscles of the soft palate, and the pharynx (superior constrictor).

Nerve-Supply.

The **inferior maxillary division of the fifth nerve** supplies all the muscles of mastication except the buccinator, which is supplied by the **facial nerve.** The internal pterygoid muscle is supplied by the nerve before its division into anterior and posterior parts; the other muscles are innervated by the anterior trunk.

Actions.

The above muscles, assisted by others in the neck, produce the various movements of the lower jaw, as follows:—

a. **Opening** and **Closure of the Jaw.**	
Weight of the jaw Digastric Mylo-hyoid Genio-hyoid Genio-hyo-glossus Infra-hyoid muscles	Masseter Temporal Internal pterygoid
b. **Protrusion** and **Retraction.**	
External pterygoid Internal pterygoid Temporal (*anterior fibres*)	Temporal (*posterior fibres*)
c. **Lateral Movement of the Jaw.**	
External pterygoid Internal „	} (*of one side*)

THE MUSCLES OF THE NECK.

The muscles in the neck include, in addition to those included in the description of the muscles of the back (p. 395), the following series: (1) sterno-cleido-mastoid; (2) the muscles of the hyoid bone (supra-hyoid and infra-hyoid); (3) the muscles of the tongue (extrinsic and intrinsic); (4) the muscles of the pharynx and soft palate; and (5) the prævertebral muscles.

The **sterno-cleido-mastoid muscle** is the prominent muscle projecting on the side of the neck. It **arises** by two heads—(1) a narrow tendinous *sternal* head, from the anterior surface of the manubrium sterni (Fig. 246, p. 322), and (2) a broader *clavicular* origin, partly tendinous, partly fleshy, from the upper surface of the clavicle in its inner third (Fig. 243, p. 319). The muscle is **inserted** into the outer surface of the mastoid process and into the superior curved line of the occipital bone (Fig. 324, p. 411).

The sterno-cleido-mastoid muscle stretches obliquely across the neck, and separates the anterior and posterior triangles from one another. Superficially it is covered by the platysma myoides muscle, the external jugular vein, and some of the superficial branches of the cervical plexus. It conceals the splenius capitis, digastric, levator anguli scapulæ, scaleni and infra-hyoid muscles, the carotid

sheath, the cervical plexus, and the spinal accessory nerve. The last-named nerve pierces the muscle.

The sterno-cleido-mastoid muscle is properly divisible into three parts: (1) **sterno-mastoid**, placed superficially, and passing obliquely from the sternum to the mastoid process; (2) **cleido-mastoid**, placed more deeply, and directed vertically upwards from the clavicle to the mastoid

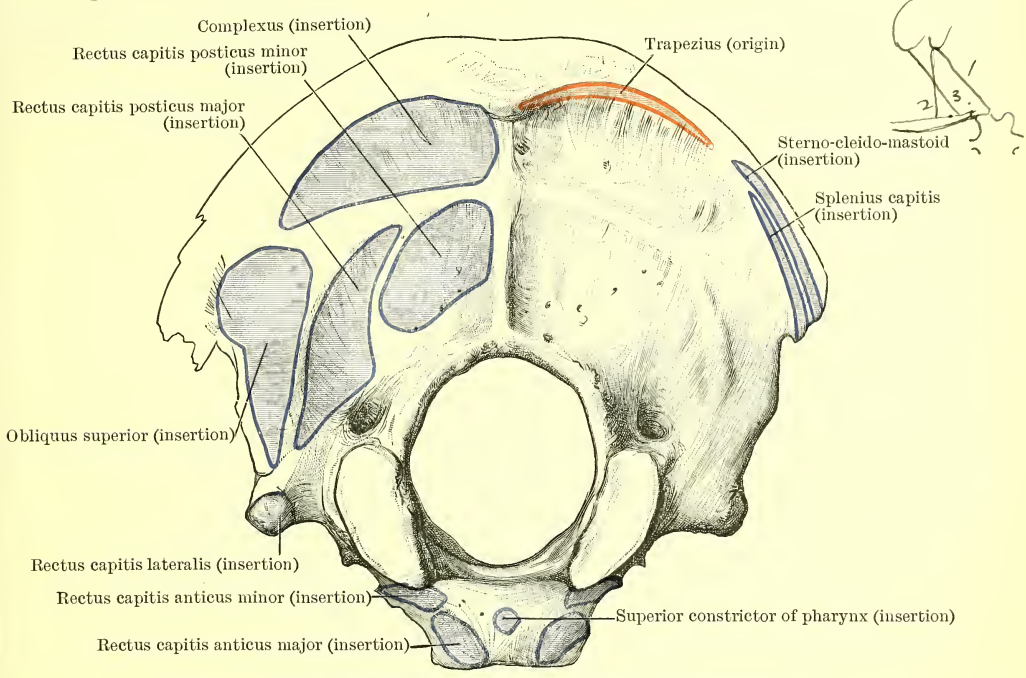


FIG. 324.—MUSCLE-ATTACHMENTS TO OCCIPITAL BONE (Inferior Surface).

process; and (3) **cleido-occipitalis**, passing obliquely upwards and backwards behind the cleido-mastoid to the superior curved line of the occipital bone.

The sterno-mastoid muscle is innervated by the spinal accessory nerve, joined by a branch from the cervical plexus (C. 2).

The action of the muscle is referred to below.

THE MUSCLES OF THE HYOID BONE.

The muscles attached to the hyoid bone are in three series: (1) infra-hyoid muscles, connecting the hyoid bone to the scapula, thorax, and thyroid cartilage; (2) supra-hyoid muscles, connecting it to the lower jaw, cranium, and tongue; and (3) the middle constrictor muscle of the pharynx.

The **infra-hyoid muscles** comprise the omo-hyoid, sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles.

The **omo-hyoid** is a muscle with two bellies, anterior and posterior. The *posterior* belly **arises** from the superior border of the scapula and the suprascapular ligament (Fig. 250, p. 325). It forms a narrow muscular band, which is directed obliquely forwards and upwards, to end in an intermediate tendon beneath the sterno-mastoid muscle. From this tendon the anterior belly proceeds upwards to be **inserted** into the outer part of the lower border of the body of the hyoid bone.

The posterior belly of the muscle separates the posterior triangle into occipital and subclavian parts; the anterior belly crosses the common carotid artery at the level of the cricoid cartilage, and in the anterior triangle forms the boundary between the muscular and carotid triangles. A process of the deep cervical fascia binds down the tendon and the posterior belly to the scapula and the first rib.

The **sterno-hyoid muscle arises** from the posterior surface of the presternum, from the back of the first costal cartilage, and from the clavicle (Fig. 243, p. 319). It passes vertically upwards in the neck, internal to the omo-hyoid and in front of the sterno-thyroid muscle, to be **inserted** into the inner part of the body of the

hyoid bone. Except near its origin the muscle lies superficially in the anterior triangle, alongside the omo-hyoid and in front of the sterno-thyroid and thyro-hyoid muscles, the trachea and the thyroid body.

The **sterno-thyroid muscle arises** beneath the sterno-hyoid from the back of the presternum and first costal cartilage. Broader than the preceding muscle, it passes upwards and slightly outwards in the neck in front of the trachea and thyroid body, and beneath the omo-hyoid and sterno-hyoid muscles, to be **inserted**

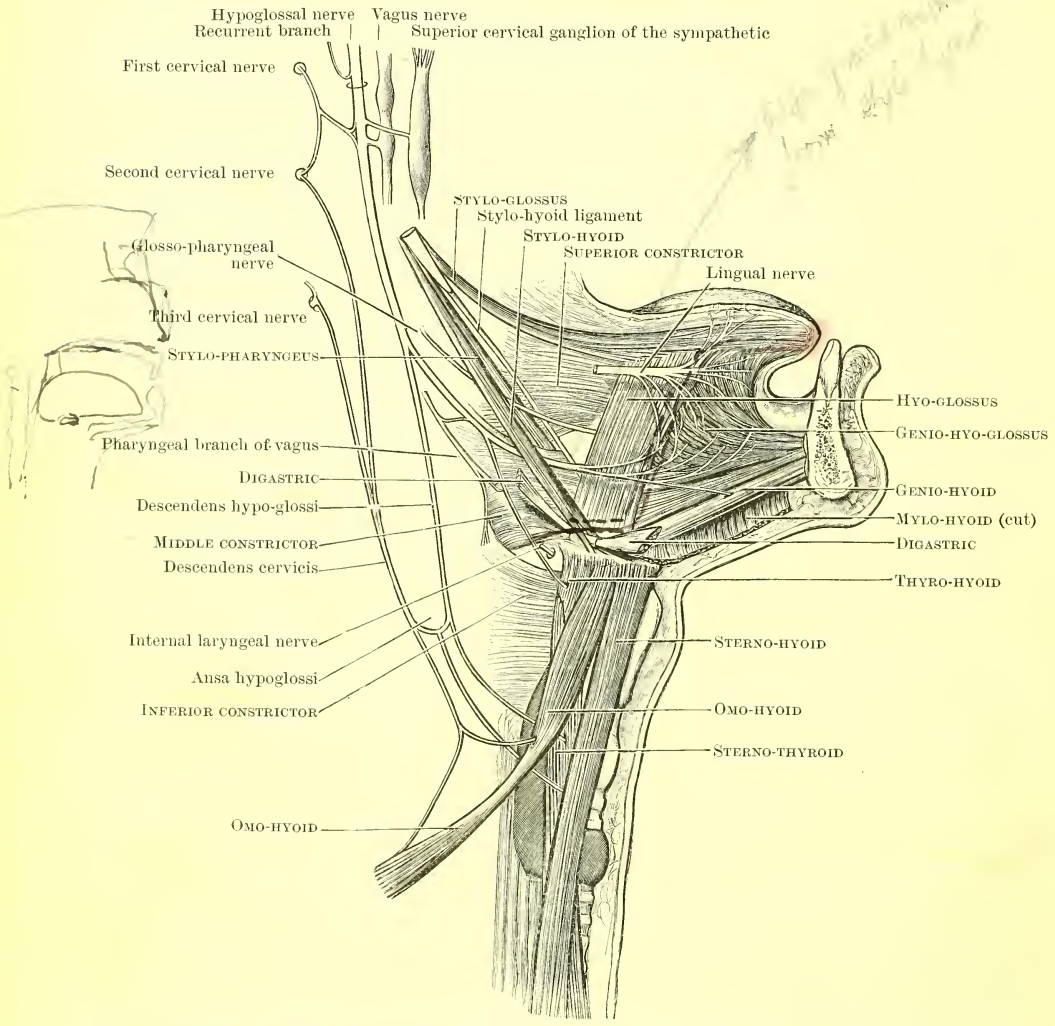


Fig. 325.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

into the oblique line of the thyroid cartilage. The muscle is marked by an oblique tendinous intersection in the middle of its length.

The **thyro-hyoid muscle** continues the line of the preceding muscle to the hyoid bone. Short and quadrilateral, it **arises** from the oblique line of the thyroid cartilage, and passing over the thyro-hyoid membrane beneath the omo-hyoid and sterno-hyoid, it is **inserted** into the body and great cornu of the hyoid bone.

The **levator glandulæ thyroideæ** is an occasional slip stretching between the hyoid bone and the isthmus or pyramid of the thyroid body.

The **supra-hyoid muscles** comprise the digastric, stylo-hyoid, mylo-hyoid, genio-hyoid muscles, and also two muscles, the genio-hyo-glossus and hyo-glossus, which will be described along with the extrinsic muscles of the tongue.

The **digastric muscle**, as its name implies, possesses two bellies—anterior and posterior. The posterior belly **arises** from the digastric groove beneath the mastoid process. It is directed forwards and downwards to end in an intermediate tendon, which is connected by a pulley-like band of cervical fascia to the body of the hyoid bone. The anterior belly of the muscle is directed forwards and upwards to the chin, and is **inserted** into an oval impression on the lower border of the mandible close to the symphysis (Fig. 327, p. 414). The muscle forms the boundary of the submaxillary space. The posterior belly is concealed at its origin by the mastoid

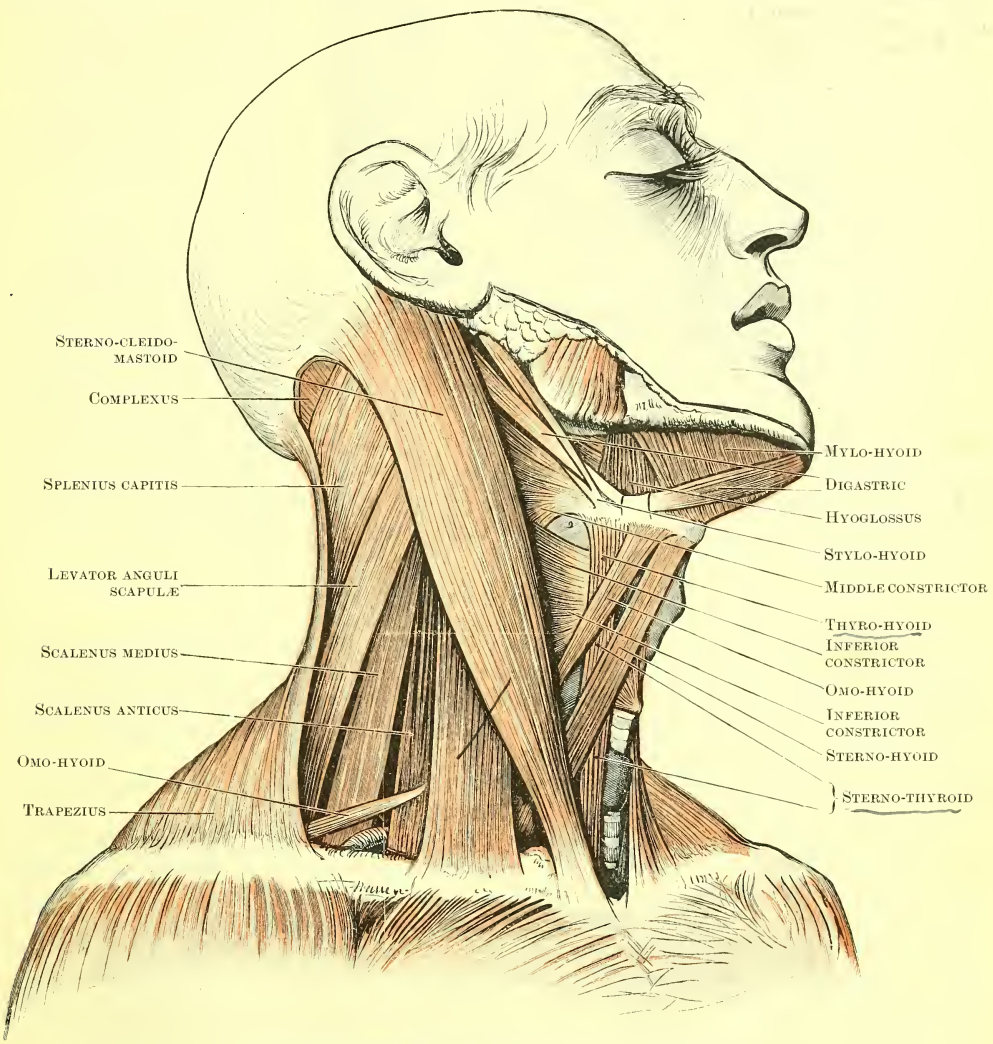


Fig. 326.—The Triangles of the Neck (Muscles).

process and the muscles attached to it. In company with the stylo-hyoid muscle it crosses the carotid vessels and the hypoglossal nerve in the anterior triangle. The anterior belly of the digastric covers the mylo-hyoid muscle.

The **stylo-hyoid muscle arises** from the styloid process of the temporal bone near its base, and is **inserted** into the body of the hyoid bone by two slips which enclose the tendon of the digastric muscle. It is directed downwards and forwards alongside the posterior belly of the digastric, and crosses the anterior triangle in front of the carotid vessels.

The **mylo-hyoid muscle arises** from the lower three-fourths of the mylo-hyoid ridge of the lower jaw (Fig. 327, p. 414). It is directed downwards and inwards, to be **inserted** into (1) the upper border of the body of the hyoid bone, and more

anteriorly (along with the opposite muscle) into (2) a median raphe extending from the hyoid bone nearly to the chin. The muscle forms a diaphragm in the floor of the mouth, and has in contact with its superficial or external surface the digastric muscle and the submaxillary gland. Its deep or internal surface is partially covered by the mucous membrane of the floor of the mouth, and is separated from the hyo-glossus and genio-hyo-glossus muscles by the deep part of the submaxillary gland, the sublingual gland, Wharton's duct and the lingual and hypoglossal nerves.

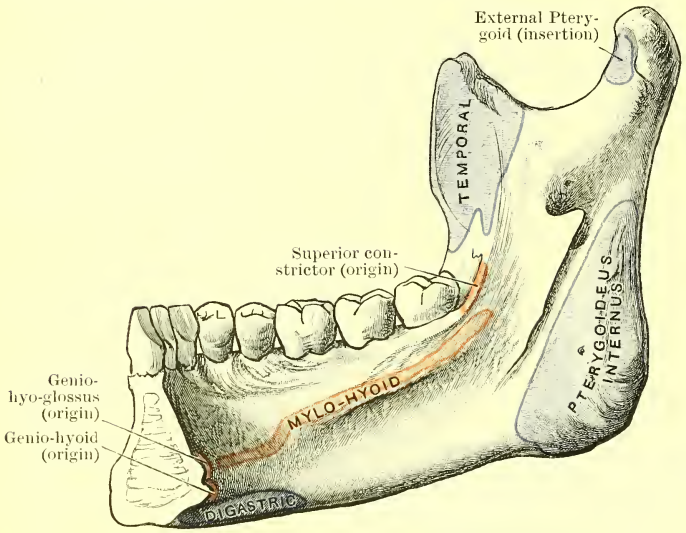


FIG. 327.—MUSCLE-ATTACHMENTS ON THE INNER SIDE OF THE LOWER JAW.

The **genio-hyoid muscle arises** from the lower of the two genial tubercles on the back of the symphysis of the lower jaw (Fig. 327, p. 414). It is directed downwards and backwards, to be **inserted** into the front of the body of the hyoid bone. The muscle lies along the lower border of the genio-hyoglossus, and is concealed by the digastric and mylo-hyoid muscles. The muscles of opposite sides are often fused together.

THE MUSCLES OF THE TONGUE.

The muscular substance of the tongue consists of two symmetrical series of muscles placed on either side of a membranous raphe in the middle line. It is composed of (1) **extrinsic muscles** arising from the soft palate, styloid process, hyoid bone and lower jaw, and (2) **intrinsic muscles** proper to the tongue itself. Each set consists of four series of muscles.

The **extrinsic muscles** are four in number: (1) genio-hyo-glossus, (2) hyo-glossus, (3) stylo-glossus, and (4) palato-glossus.

The **genio-hyo-glossus muscle** (Fig. 325) is an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It is a fan-shaped muscle **arising** by its apex from the upper of the two genial tubercles behind the symphysis of the lower jaw (Fig. 327, p. 414). From this origin the muscular fibres diverge; the lowest fibres are directed downwards and backwards, to be **inserted** into the body of the hyoid bone; the highest fibres curve forwards, to be attached to the tip of the tongue; the intermediate fibres are attached to the substance of the tongue in its whole length between the base and tip. The muscles of opposite sides are separated by the median raphe of the tongue. On the outer side of each are the hyo-glossus and mylo-hyoid muscles. Between the hyo-glossus and genio-hyo-glossus are placed the stylo-hyoid ligament, the lingual artery, and the glosso-pharyngeal nerve.

The **hyo-glossus muscle** is also an extrinsic muscle of the tongue as well as a supra-hyoid muscle. It **arises** from the hyoid bone (body and great cornu), and is directed upwards and forwards, to be **inserted** into the side of the tongue, its fibres interlacing at its insertion with the fibres of the stylo-glossus. The muscle is quadrilateral, and lies between the genio-hyo-glossus and mylo-hyoid muscles, separated from the latter by the mucous membrane of the floor of the mouth, the sublingual and part of the submaxillary glands, the lingual and hypoglossal nerves, and Wharton's duct.

The **chondro-glossus** is a small separated slip of the hyo-glossus, not always present.

The **stylo-glossus muscle arises** beneath the parotid gland from the lower end

of the styloid process and from the stylo-mandibular ligament. It sweeps forwards and inwards, and is **inserted** into the side and under surface of the tongue, its fibres spreading out to decussate with those of the palato-glossus and hyo-glossus muscles. It is covered by the internal pterygoid muscle and by the mucous membrane of the tongue.

The **palato-glossus** is a thin sheet of muscular fibres **arising** from the under surface of the soft palate, where it is continuous with fibres of the opposite muscle. It passes downwards in the anterior pillar of the fauces, and spreads out, to be **inserted** into the sides of the tongue, blending with the stylo-glossus and the deep transverse fibres of the tongue. The muscle is placed directly beneath the mucous membrane of the soft palate and tongue.

Intrinsic Muscles of the Tongue.—Besides receiving the fibres of insertion of the extrinsic muscles, the substance of the tongue is composed of four intrinsic muscles on either side, two in the sagittal plane, the superior and inferior linguales; two in the coronal plane, the transverse and vertical fibres.

The **superior lingualis muscle** extends from base to tip of the tongue, placed on its dorsum immediately under the mucous membrane, into which many of its fibres are inserted.

The **inferior lingualis** is a cylindrical band of muscular fibres occupying the under part of the organ on each side, in the interval between the genio-hyo-glossus and the hyo-glossus muscles. Posteriorly some of its fibres extend to the hyoid bone.

The **transverse fibres** arise from the median raphe, and radiate outwards to the dorsum and sides of the tongue, decussating with the extrinsic muscles and the fibres of the vertical muscle. They occupy the substance of the tongue between the superior and inferior linguales.

The so-called **vertical fibres** arise from the dorsal surface of the tongue, and sweep downwards and outwards to its sides, intermingled with the fibres of the previous muscle and the insertions of the extrinsic muscles. These two muscles form a very considerable part of the total muscular substance of the organ.

Nerve-Supply.

The muscles of the hyoid bone and of the tongue are for the most part supplied by the **ansa cervicalis** (C. 1. 2. 3.) and by the **hypoglossal nerve.** A few of the muscles are supplied by the trigeminal, facial, and spinal accessory nerves.

Muscles.	Nerves.	Origin.
Omo-hyoid Sterno-hyoid Sterno-thyroid	Ansa cervicalis	C. 1. 2. 3.
Thyro-hyoid Genio-hyoid Genio-hyo-glossus	Hypoglossal	C. 1. 2.
Hyo-glossus Stylo-glossus Intrinsic muscles of tongue	Hypoglossal	Hypoglossal.
Palato-glossus	Pharyngeal plexus	Spinal accessory.
Mylo-hyoid Digastric Anterior belly	Mylo-hyoid branch of inferior dental nerve	Trigeminal.
Digastric Posterior belly Stylo-hyoid	Facial	Facial.

Actions.

These muscles have a complexity of action, owing to their numerous attachments to more or less movable points. The movements for which they are responsible in whole or part are (1) movements of the hyoid bone in mastication and deglutition, (2) movements of the thyroid cartilage, (3) movements of the tongue, (4) movements of the head, (5) movements of the shoulder, and (6) respiration.

(1) **Movements of the Hyoid Bone.**—The hyoid bone is elevated or depressed, and moved

forwards or backwards along with the lower jaw and tongue, in speech, mastication, and swallowing.

a. **Elevation** and **Depression.**		*b.* **Protraction** and **Retraction.**	
Digastric	Thyro-hyoid	Genio-hyoid	Stylo-hyoid
Stylo-hyoid	Sterno-hyoid	Genio-hyo-glossus	Middle constrictor
Mylo-hyoid	Omo-hyoid		
Genio-hyoid	Sterno-thyroid		
Genio-hyo-glossus			
Hyo-glossus			
Muscles closing the mouth			

(2) **Movements of the Thyroid Cartilage.**—The thyroid cartilage is raised and lowered during speech and deglutition.

Elevation.	**Depression.**
Thyro-hyoid	Sterno-thyroid
Stylo-pharyngeus	Crico-thyroid
Palato-pharyngeus	Depressors of hyoid bone
Elevators of hyoid bone	
Muscles closing mouth	

(3) **Movements of the Tongue.**—The chief movements of the tongue in speech and deglutition are elevation and depression, protrusion and retraction, and lateral movements.

a. **Elevation** and **Depression.**	
Stylo-glossus (base)	Genio-hyo-glossus
Palato-glossus	Hyo-glossus
Muscles elevating hyoid bone	Chondro-glossus
Muscles closing mouth	Muscles depressing the hyoid bone

b. **Protrusion** and **Retraction.**	
Genio-hyo-glossus (*posterior fibres*)	Genio-hyo-glossus (*anterior fibres*) Stylo-glossus
c. **Lateral Movements.**—The muscles of one side only.	

(4) **Movements of the Head.**—The sterno-mastoid muscles, acting together, flex the head on the spinal column, assisted by the supra-hyoid and infra-hyoid muscles. The sterno-mastoid muscle of one side, acting alone, bends the head to the same side, and simultaneously rotates it to the opposite side, as seen in *torticollis* (wryneck).

(5) **Movements of the Shoulder Girdle.**—The omo-hyoid and sterno-mastoid muscles have already been included among the elevators of the shoulder girdle.

(6) **Respiration.**—The muscles in the front of the neck are auxiliary muscles in extraordinary or difficult inspiration. The masseter and temporal muscles fix the lower jaw; the hyoid bone is raised and fixed by the supra-hyoid muscles; and the sternum is raised by the sterno-mastoid and infra-hyoid muscles.

The Muscles of the Pharynx.

The muscular envelope of the pharynx is composed of two strata. The *external* or *circular layer* consists of the three constrictor muscles; the *internal* or *longitudinal layer* consists of the fibres of the stylo-pharyngeus and palato-pharyngeus muscles.

The **superior constrictor muscle** is triangular or fan-shaped. It arises successively from the lower half of the posterior border of the internal pterygoid plate, from the pterygo-mandibular ligament, from the mylo-hyoid ridge of the

lower jaw (Fig. 327, p. 414), and from the mucous membrane of the floor of the mouth (*glosso-pharyngeus*). The muscular fibres radiate backwards, and are **inserted** for the most part into a median raphe extending down the back wall of the pharynx in the middle line. The highest fibres are attached to the pharyngeal spine of the occipital bone (Fig. 333, p. 421), and the lowest fibres are overlapped by the middle constrictor. A crescentic interval occurs above the muscle, below the base of the skull, in which the Eustachian tube and the levator and tensor palati muscles appear. Its lower border is separated from the middle constrictor by the stylo-pharyngeus muscle and the glosso-pharyngeal nerve. The superior constrictor muscle separates the internal carotid artery from the cavity of the pharynx and tonsil.

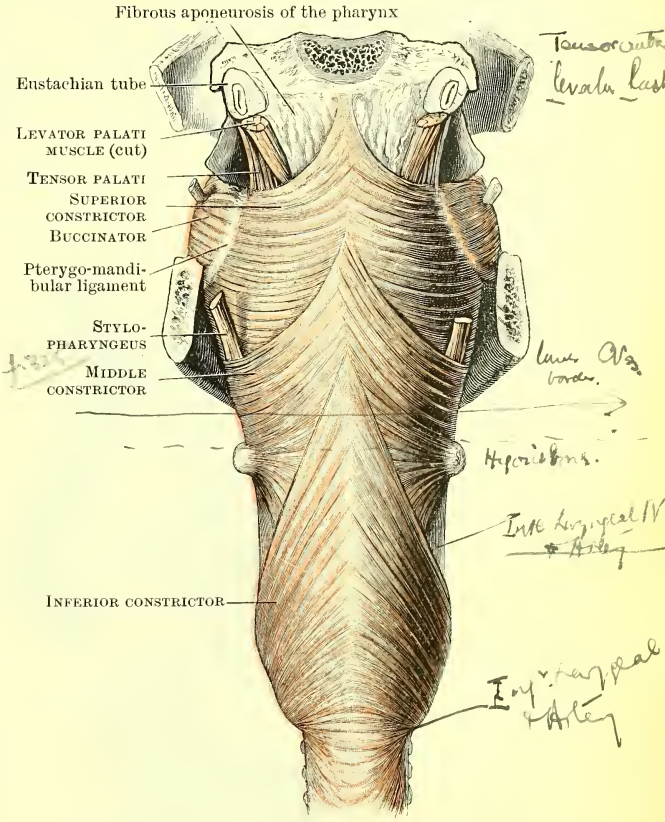


Fig. 328.—Posterior View of the Pharynx and Constrictor Muscles.

The **middle constrictor muscle arises** from the stylo-hyoid ligament and from both cornua of the hyoid bone. From its origin the muscular fibres radiate backwards, to be **inserted** into the median raphe on the posterior aspect of the pharynx. The upper fibres overlap the lower part of the superior constrictor; the lower fibres are concealed from view by the inferior constrictor muscle. In the interval between the middle and inferior constrictors are found the internal laryngeal artery and nerve.

The **inferior constrictor muscle arises** from the oblique line of the thyroid cartilage, and from the side of the cricoid cartilage. Its fibres radiate backwards, to be **inserted** into the median raphe on the back of the pharynx, the upper fibres overlapping the lower part of the middle constrictor, the lower fibres blending with the muscular fibres of the œsophagus. Below the lower border of the muscle the inferior laryngeal artery and nerve enter into relation with the larynx.

The **deeper longitudinal stratum** of muscles in the pharyngeal wall is composed of the insertions of the stylo-pharyngeus and palato-pharyngeus muscles.

The **stylo-pharyngeus arises** from the root of the styloid process on its inner side, and passes downwards between the external and internal carotid arteries. It enters the wall of the pharynx in the interval between the superior and middle constrictor muscles. Spreading out beneath the middle constrictor muscle, it is **inserted** into the superior and posterior borders of the thyroid cartilage and into the wall of the pharynx itself, becoming continuous posteriorly with the palato-pharyngeus. In the neck the glosso-pharyngeal nerve winds round it on its way to the tongue.

The **palato-pharyngeus** occupies the soft palate and the pharyngeal wall. In the substance of the soft palate it consists of two layers, a postero-superior layer, thin, and continuous across the middle line with the corresponding layer on the opposite side, and an antero-inferior layer, which is thicker, and is attached to the posterior border of the hard palate. The levator palati and azygos uvulæ muscles are enclosed between the two layers, which unite at the posterior edge of the palate, receiving at the same time additional fibres arising from the Eustachian tube (*salpingo-pharyngeus*). The muscle descends to the pharynx in the posterior pillar

of the fauces. Its fibres spread out in the form of a thin sheet in the wall of the pharynx, in continuity anteriorly with the stylo-pharyngeus, and are **inserted** into the posterior border of the thyroid cartilage, and behind that into the aponeurosis of the pharynx, reaching down as far as the lower border of the inferior constrictor. The muscle is placed beneath the middle and inferior constrictors in the pharyngeal wall, and the fibres of the muscles of opposite sides decussate in the middle line beneath the median raphe.

The Muscles of the Soft Palate.

The soft palate and uvula form a muscular fold, covered on each surface by mucous membrane, projecting backwards into the pharynx, and forming the posterior part of the roof of the mouth.

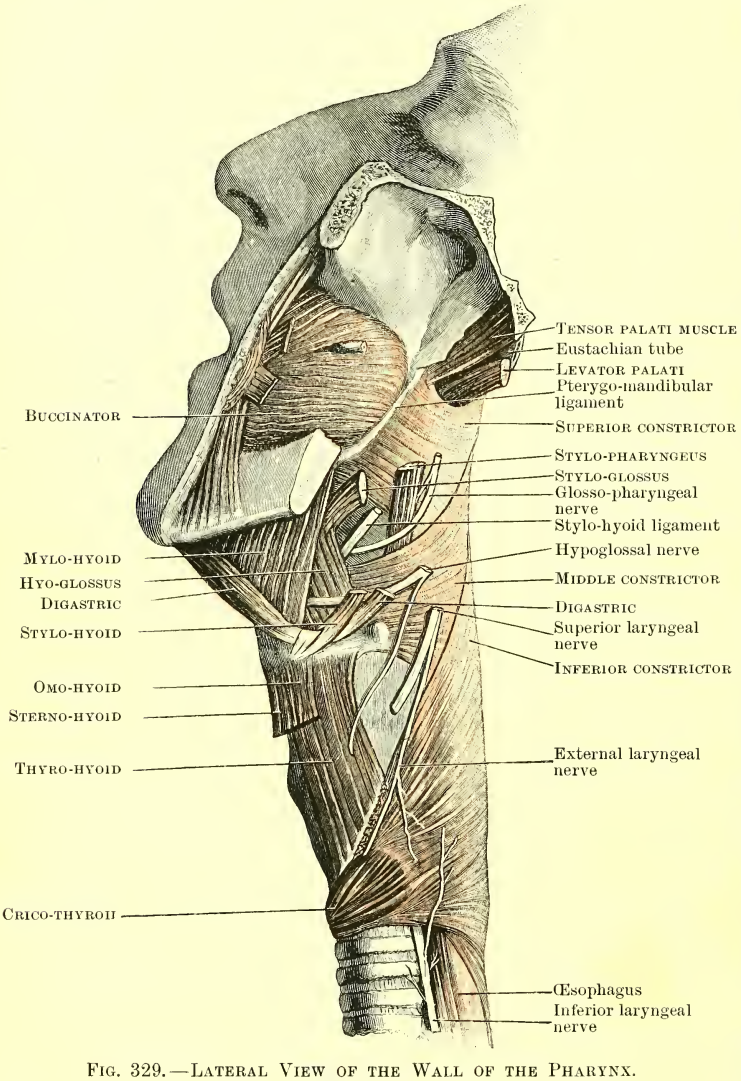


Fig. 329.—Lateral View of the Wall of the Pharynx.

The muscular fold is composed of five pairs of muscles—the palato-pharyngeus (and salpingo-pharyngeus), azygos uvulæ, levator palati, tensor palati, and palato-glossus.

The **palato-pharyngeus** muscle has been already described (p. 417) among the muscles of the pharynx.

The **azygos uvulæ** consists of two narrow bundles enclosed, along with the insertion of the levator palati, between the layers of the palato-pharyngeus. The slips **arise** from the posterior nasal spine and the aponeurosis of the soft palate, and unite as they proceed backwards to end in the uvula.

The **levator palati** has a double **origin**: (1) from the under surface of the apex of the petrous portion of the temporal bone, and (2) from the lower part of the cartilaginous Eustachian tube. It passes obliquely downwards and inwards, across the upper border of the superior constrictor muscle, and enters the soft palate between the two layers of the palato-pharyngeus muscle. It is **inserted** into the aponeurosis of the soft palate, and some of its fibres become continuous with those of the opposite muscle. It is separated from the tensor

palati muscle by the Eustachian tube and the deeper layer of the palato-pharyngeus muscle.

The **tensor (circumflexus) palati** arises (1) from the scaphoid fossa and the alar spine of the sphenoid bone, and (2) from the outer side of the cartilaginous Eustachian tube. It descends between the internal pterygoid muscle and the internal pterygoid plate, and ends in a tendon which hooks round the hamular process, and is **inserted** beneath the levator palati into the posterior border of the hard palate, and into the aponeurosis of the soft palate.

The **palato-glossus muscle,** occupying the under surface of the soft palate and the anterior pillar of the fauces, has already been described with the muscles of the tongue (p. 415).

Nerve-Supply.

The chief nerve supplying the muscles of the pharynx and soft palate is the **spinal accessory nerve,** aided by the **fifth** (otic ganglion) and the **ninth** (glosso-pharyngeal) nerves and the laryngeal branches of the **vagus nerve.**

Muscles.	Nerves.	Origin.
Constrictors of pharynx Palato-glossus Palato-pharyngeus Levator palati Azygos uvulæ	Pharyngeal plexus	XI.
Tensor palati	Otic ganglion	V.
Stylo-pharyngeus	Glosso-pharyngeal	IX.
Inferior constrictor	External laryngeal Inferior laryngeal	X.

Actions.

The muscles of the pharynx and soft palate are chiefly brought into action in **the act of swallowing.** This act is divided into a *voluntary stage*, in which the bolus lies in front of the pillars of the fauces, and an *involuntary stage*, during which the food passes from the mouth through the pharynx. The movements occurring during the passage of food through the mouth are as follows: the cheeks are compressed by the action of the buccinator muscles; the tongue, hyoid bone, and thyroid cartilage are successively raised upwards by the action of the muscles which close the mouth and elevate the hyoid bone. By these means the food is pushed backwards between the pillars of the fauces.

At the same time, by the contraction of the palato-glossus and palato-pharyngeus, the pillars of the fauces are narrowed, while the muscles of the soft palate, contracting, tighten the soft palate, and by bringing it in contact with the posterior wall of the pharynx, shut off the upper (nasal) portion of the cavity. The elevation of the tongue, hyoid bone, and larynx simultaneously causes the elevation of the epiglottis and the aperture of the glottis, which is closed by the approximation of the arytenoid cartilages and the combined action of laryngeal muscles (arytenoideus, thyro-arytenoideus, and thyro-aryteno-epiglottideus). The food thus slips over the posterior surface of the epiglottis and the closed aperture of the glottis, and between the pillars of the fauces on either side, into the pharynx. It is now clasped by the constrictor muscles, which, by their contractions, force it down into the œsophagus. The contraction of the constrictor muscles results in a flattening of the pharynx and elevation of its anterior attachments.

During the act of swallowing, it is generally thought that the Eustachian tube is opened by the contraction of the tensor palati muscle which arises from it. It has been held, on the other hand, that the Eustachian tube is closed during swallowing by the compression of its wall by the contraction of the levator palati.

Deep Lateral and Prævertebral Muscles of the Neck.

Three series of muscles are comprised in this group: (1) vertebro-costal (scaleni, anticus, medius, and posticus), (2) vertebro-cranial (recti capitis antici, major and minor, and lateralis), and (3) vertebral (longus colli).

The **scalenus anticus arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descends behind the carotid sheath, to be **inserted** into the scalene tubercle and ridge on the first rib (Fig. 330, p. 420). In front of the muscle are the subclavian and internal jugular veins, and the nerves descending through the neck. Behind, it is

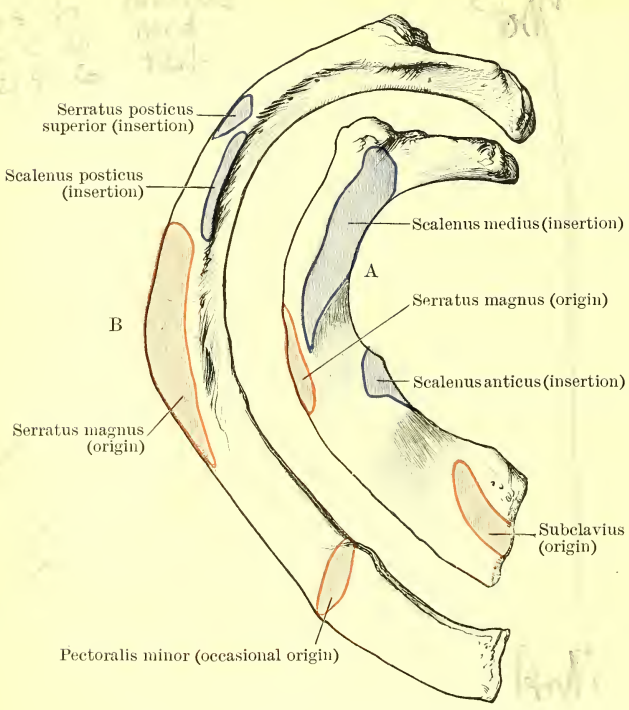


FIG. 330.—MUSCLE-ATTACHMENTS TO THE UPPER SURFACE OF THE FIRST RIB, AND THE OUTER SURFACE OF THE SECOND RIB.

A, First rib; B, Second rib.

and sixth cervical transverse processes, and is **inserted** into a linear impression on the outer side of the second rib. It is concealed behind by the levator anguli scapulæ, and is in contact anteriorly with the scalenus medius.

The **rectus capitis anticus major arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ. It forms a flat triangular muscle, which is directed upwards, to be **inserted** into an impression on the under surface of the basilar process of the occipital bone in front and to the outer side of the pharyngeal spine (Fig. 333, p. 421). It lies on the cervical vertebræ behind the carotid vessels and the separated from the scalenus medius by the cords of the brachial plexus, the subclavian artery, and the pleura.

The **scalenus medius arises** from the posterior tubercles of the transverse processes of the cervical vertebræ, from the second to the sixth inclusive. It descends in the floor of the posterior triangle, to be **inserted** into the rough impression on the first rib behind the subclavian artery (Fig. 330, p. 420). The muscle is covered anteriorly by the cords of the brachial plexus, the subclavian artery, and the omohyoid muscle, and is in contact behind with the levator anguli scapulæ and the scalenus posticus. It is pierced by the posterior scapular and posterior thoracic nerves.

The **scalenus posticus arises** from the posterior tubercles of the fourth, fifth,

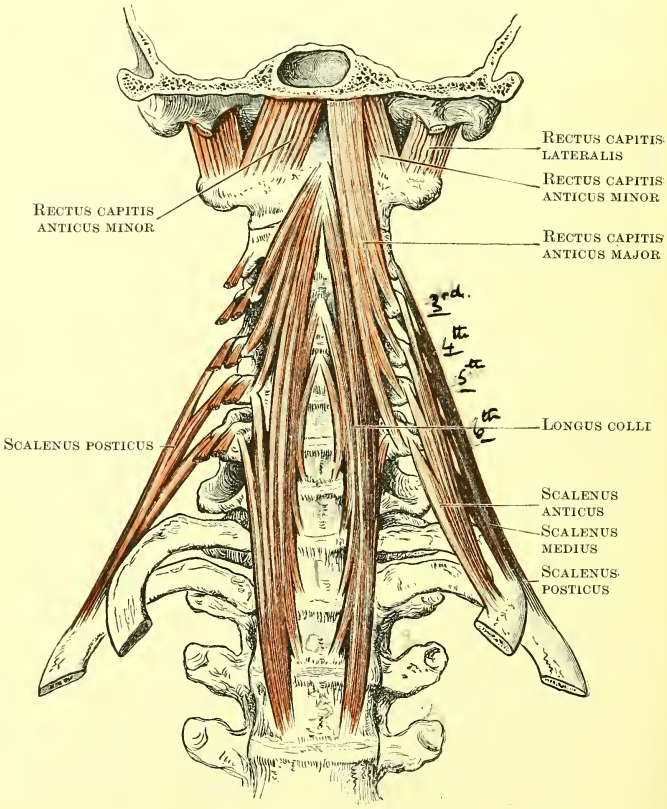


FIG. 331.—THE PRÆVERTEBRAL MUSCLES OF THE NECK.

pharynx, external to the longus colli, and internal at its origin to the scalenus anticus.

The **rectus capitis anticus minor** **arises** from the anterior arch of the atlas, and

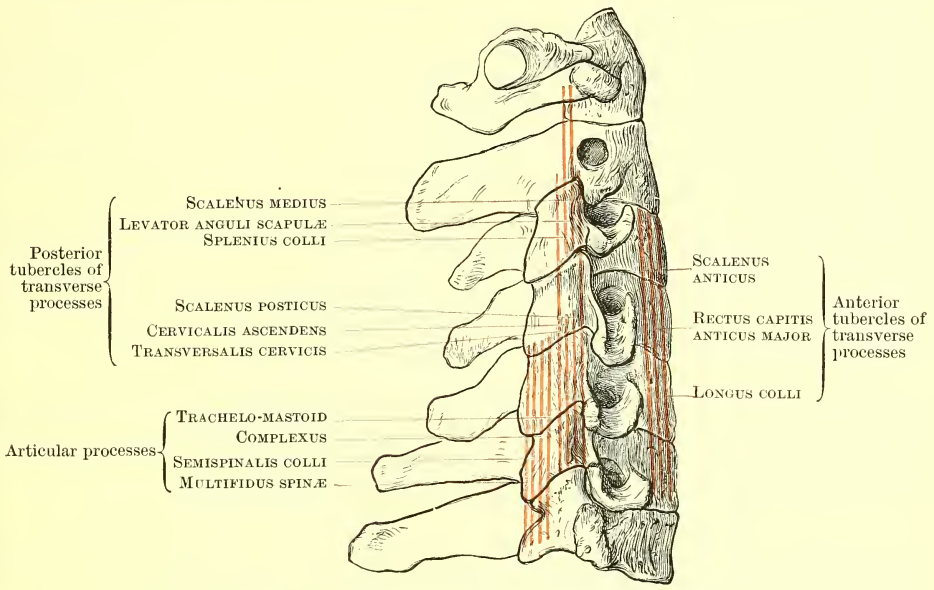


Fig. 332.—Scheme of Muscular-Attachments to Cervical Vertebræ.

is **inserted** into the basilar process between the previous muscle and the occipital condyle (Fig. 333, p. 421). It is concealed by the rectus capitis anticus major.

The **longus colli** is a flattened muscular band extending from the third thoracic

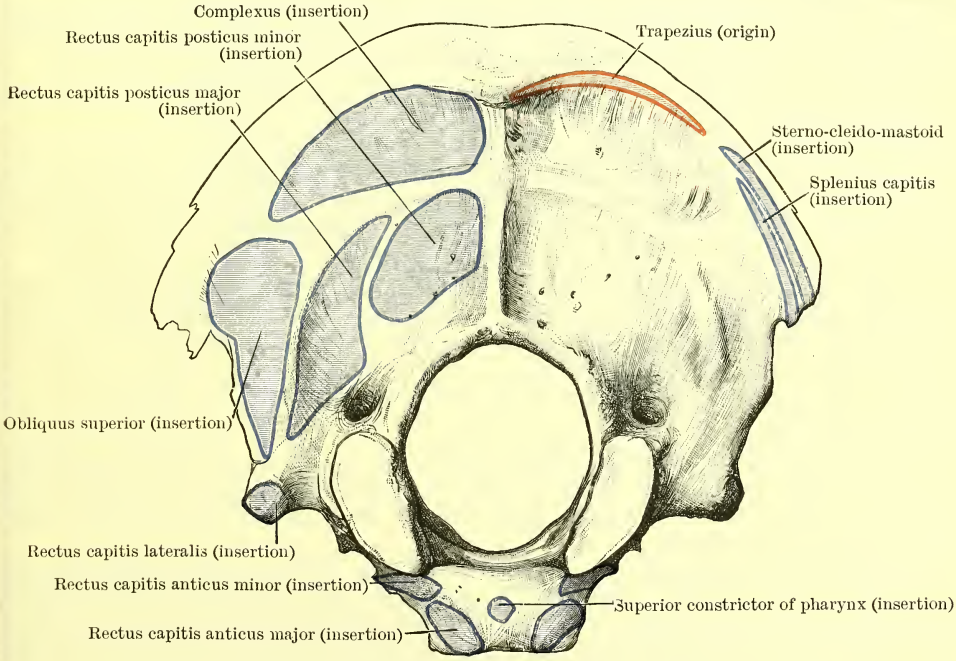


Fig. 333.—Muscle-Attachments to Occipital Bone (Inferior Surface).

vertebra to the atlas. It is divisible into three portions—a vertical, a lower oblique, and an upper oblique portion.

The **vertical portion** of the muscle **arises** from the bodies of the first three

thoracic and the last three cervical vertebræ; and passing vertically upwards, it is **inserted** into the bodies of the second, third, and fourth cervical vertebræ.

The **lower oblique portion arises** from the bodies of the first three thoracic vertebræ, and is **inserted** into the anterior tubercles of the fifth and sixth cervical vertebræ.

The **upper oblique portion arises** from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ, and is directed upwards, to be **inserted** into the anterior tubercle of the atlas.

The longus colli muscle clothes the front of the vertebral column in the neck, and is separated by the deep cervical fascia from the carotid vessels, pharynx, and œsophagus.

The **rectus capitis lateralis**, in series with the posterior inter-transverse muscles in the neck, **arises** from the transverse process of the atlas, and is **inserted** into the under surface of the ex-occipital bone. It is placed alongside the recti capitis antici, separated from them by the anterior primary division of the first cervical nerve.

Nerve-Supply.

The prævertebral muscles are all supplied by anterior primary divisions of the **cervical spinal nerves**: the rectus capitis anticus minor, and rectus capitis lateralis, by the loop between the first two nerves; the rectus capitis anticus major by the first four; the longus colli by the second, third, and fourth; the scaleni by the lower four or five cervical nerves.

Actions.

The movements produced by these muscles are considered along with those of other muscles acting on the head, spinal column, and thorax (pp. 398, 426).

THE MUSCLES OF THE THORAX.

Muscles of Respiration.

The muscles which complete the boundaries of the thorax are the diaphragm and intercostal muscles (external and internal), along with three series of smaller muscles—the triangularis sterni, the levatores costarum, and the infra-costales.

The **intercostal muscles** are arranged in eleven pairs, forming thin layers filling up the intercostal spaces.

Each **external muscle arises** from the sharp lower border of a rib, and is directed downward and forward, to be **inserted** into the outer edge of the upper border of the rib below. It extends from the tubercle of the rib behind nearly to the costal cartilage in front. The *anterior intercostal aponeurosis* is continuous with it anteriorly, and extends forwards to the side of the sternum.

Each **internal muscle arises** from the costal cartilage and the inner edge of the subcostal groove, and is directed downwards and backwards, to be **inserted** into the inner edge of the upper border of the rib and costal cartilage below. It extends from the side of the sternum in front to the angle of the rib behind, where it becomes continuous with the *posterior intercostal aponeurosis* extending to the tubercle of the rib.

The external intercostal muscles are covered by the pectoral muscles, serratus magnus, and the muscles of the back; the internal muscles are in contact with the pleura. The intercostal vessels and nerve lie between the two muscles in the posterior part of the thorax.

The **levatores costarum** are in series with the external intercostal muscles. They are twelve small slips **arising** from the transverse processes of the seventh cervical and upper eleven thoracic vertebræ. They spread out in a fan-like manner as they descend, to be **inserted** into the outer surface of the ribs posterior to the angles. They lie under cover of the longissimus dorsi muscle.

The **infra-costales** (subcostales) are slips of muscles found on the inner surface of the lower ribs near their angles. They are in series with the internal intercostal muscles, but pass over the deep surface of several ribs.

The **triangularis sterni** (m. transversus thoracis) occupies the posterior aspect

of the anterior thoracic wall. It **arises** from the back of the ensiform cartilage and mesosternum as high as the level of the third costal cartilage. From this origin its fibres radiate outwards, the lower ones horizontally, the upper ones obliquely upwards, to be **inserted** into the costal cartilages of all the true ribs except the first and seventh. The muscle lies against the pericardium and pleura. It is separated from the chest wall by the internal mammary vessels and the anterior branches of the intercostal nerves. The muscle is continuous below with the transversalis abdominis.

The **diaphragm** is the great membranous and muscular partition separating the cavities of the thorax and abdomen. It forms a thin lamella arching over

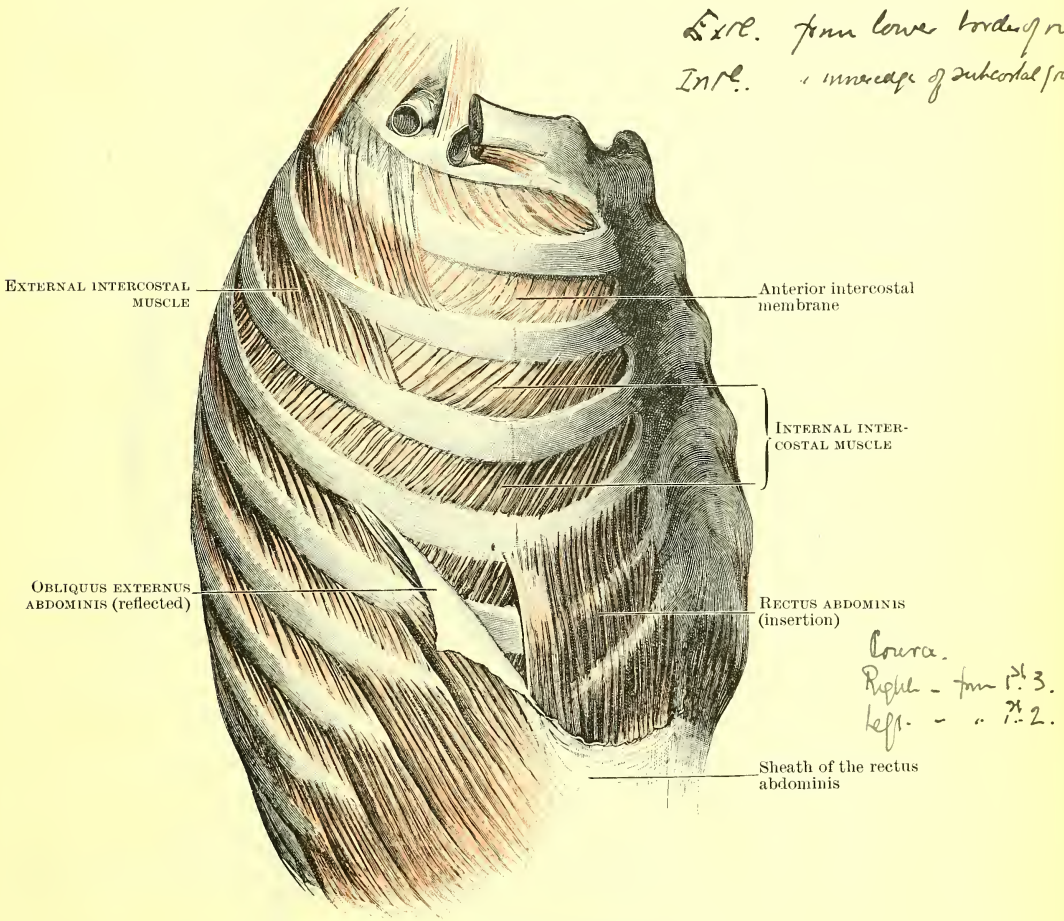


Fig. 334.—The Muscles of the Thoracic Wall.

the liver, stomach, and spleen, with its convex upper surface in contact with the pericardium, pleuræ, and chest wall. It possesses a peripheral origin from the sternum, ribs, and vertebral column, and an insertion into a central tendon. It **arises** (1) *anteriorly* from the posterior surface of the ensiform cartilage by two slender fleshy slips, directed backwards; (2) *laterally*, from the deep surface of the lower six costal cartilages on each side by fleshy bands which interdigitate with those of the transversalis abdominis; (3) *posteriorly*, from the lumbar vertebræ, by the crura, and from the arcuate ligaments. The **crura** are two elongated fibro-muscular bundles which arise from the front of the bodies of the lumbar vertebræ, on the right side from the first three, on the left side from the first two vertebræ. They are directed upwards and, passing in front of the aorta, decussate across the middle line in front of that vessel, the fibres of the right crus passing in front of those of the left crus. The fibres then encircle the œsophagus, forming an elliptical opening

for its passage, and finally join the central tendon, after a second decussation in front of the gullet.

The **arcuate ligaments** are five in number.

The **middle arcuate ligament** is a fibrous arch connecting together the crura of the diaphragm in front of the aorta, and giving origin to fibres which join the crura as they decussate to encircle the gullet.

The **internal arcuate ligament** is a thickening formed by the attachment of the psoas fascia to the body of the first lumbar vertebra internally and its transverse process externally. Stretching across the upper end of the psoas muscle, the ligament gives origin to muscular fibres directed upwards on each side of the crura.

The **external arcuate ligament** is the thickened upper end of the fascia over the quadratus lumborum (anterior layer of the lumbar fascia), and is attached internally to the transverse process of the first lumbar vertebra, and externally to the

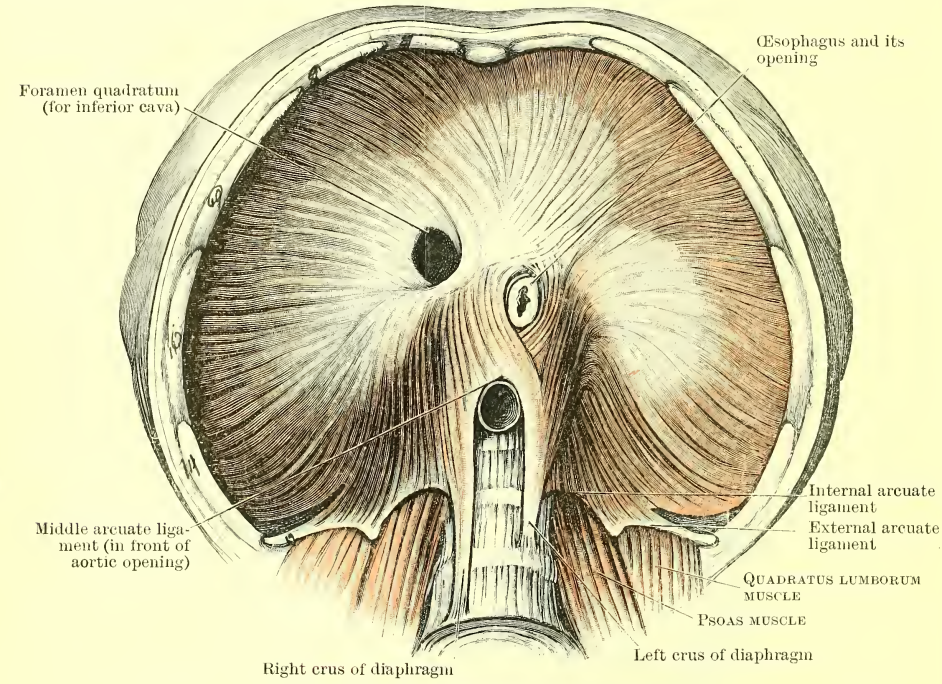


FIG. 335.—THE DIAPHRAGM (from below).

last rib. It gives origin to another broad band of muscular fibres, separated from those arising from the internal arcuate ligament by an interval, and passing upwards to the central tendon of the diaphragm.

From this extensive origin the muscular fibres of the diaphragm converge to an **insertion** into a large trilobed **central tendon**. Of its lobes the right one is the largest, the middle or anterior is intermediate in size, and the left is the smallest. It does not occupy the centre of the muscle, being placed nearer the front than the back. The fibres of the crura are consequently the longest; those from the sternum are the shortest.

The diaphragm is pierced by numerous structures. The superior epigastric artery enters the sheath of the rectus abdominis between its sternal and costal origins; the musculo-phrenic artery passes between its attachments to the seventh and eighth ribs. The sympathetic cord and the splanchnic nerves pierce or pass behind the diaphragm; the last thoracic nerve passes beneath the external arcuate ligament; and the aorta, the vena azygos major, and thoracic duct pass between the crura, underneath the middle arcuate ligament (*aortic opening*). The special foramina are two in number. The *foramen quadratum* in the right lobe of the central tendon transmits the inferior vena cava, and small branches of the right

phrenic nerve. The *œsophageal opening* is in the muscular substance of the diaphragm, behind the central tendon, and is surrounded by a sphincter-like arrangement of the crural fibres. Besides the œsophagus, this opening transmits the two pneumogastric nerves. The upper convex surface of the diaphragm forms the sloping floor of the thorax, and is in contact with the pleuræ and the pericardium (which is firmly bound down to the central tendon, and less firmly to the

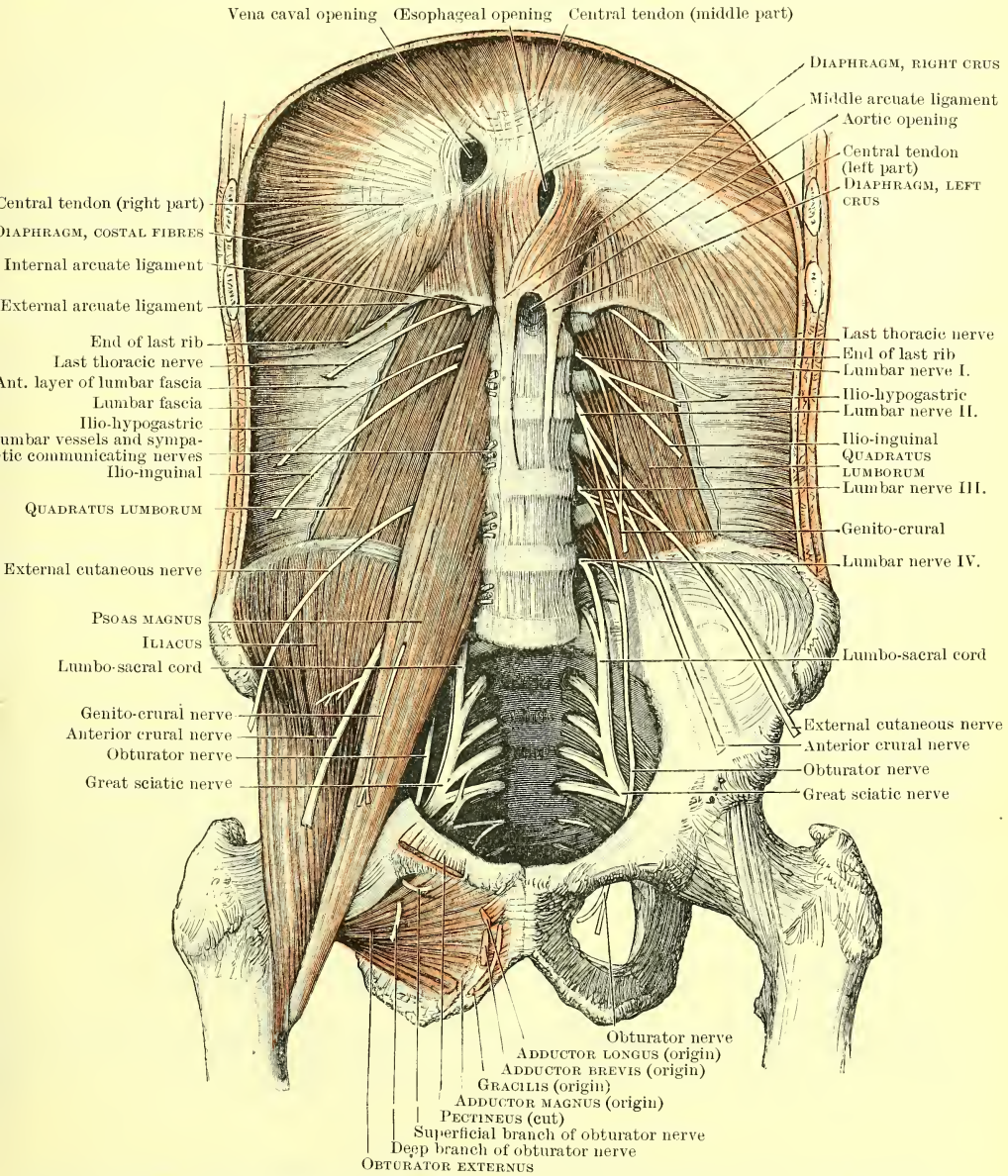


Fig. 336.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

muscular fibres on the left side). By its lateral margins the diaphragm is in contact on each side with the thoracic wall beyond the reflection of the pleura, and behind with the œsophagus and descending thoracic aorta. The under surface of the diaphragm is concave, and is for the most part invested by peritoneum. It is in relation with the liver, stomach, spleen, kidneys, suprarenal bodies, duodenum and pancreas, the inferior vena cava, and the branches of the cœliac axis. Its vault is higher on the right side than on the left, owing to the upward projection of the liver on that side.

The diaphragm is found as a complete septum between the thorax and abdomen only in mammals. It is occasionally deficient in the human subject, producing *hernia of the diaphragm*, either into the pericardial cavity through the central tendon, or into the thoracic cavity through the lateral portions of the muscle. A rare condition is congenital deficiency of a part of the lateral half of the muscle, generally placed posteriorly, and on the left side. This produces, by continuity of the peritoneum and pleura behind the diaphragm, a *congenital diaphragmatic hernia.*

Nerve-Supply.

The intercostal muscles, levatores costarum, infra-costal muscles, and triangularis sterni, are all supplied by the anterior primary divisions of the **intercostal nerves.** The diaphragm receives its chief, if not its entire, motor supply from the **phrenic nerves** (C. 3. 4. 5.) It is innervated also by the diaphragmatic plexus of the sympathetic, and is said to receive fibres from the lower intercostal nerves.

Actions.

The act of respiration consists of two opposite movements, inspiration and expiration.

1. The **movement of expiration** is performed by (1) the elasticity of the lungs, (2) the weight of the chest walls, (3) the elevation of the diaphragm, (4) the action of muscles—triangularis sterni and muscles of the abdominal wall. It is sometimes stated that the interosseous fibres of the internal intercostal muscles are depressors of the ribs.

2. The **movement of inspiration** results in the enlargement of the thoracic cavity in all its diameters. Its antero-posterior and transverse diameters are increased by the elevation and forward movement of the sternum, and by the elevation and eversion of the ribs, while its vertical diameter is increased by the descent of the diaphragm.

The muscles of **inspiration** are divided into two series—ordinary and accessory.

a. **Ordinary Muscles.**	*b.* **Extraordinary and Accessory Muscles**
Diaphragm	Quadratus lumborum
Intercostals	Pectorales
Scaleni	Serratus magnus
Serrati postici	Sterno-mastoid
Levatores costarum	Latissimus dorsi
	Infra-hyoid muscles
	Extensors of the spine

Of the ordinary muscles the diaphragm is the most important. Its action is twofold—**centrifugal**, elevating the ribs and increasing the transverse and antero-posterior diameters of the thorax, and **centripetal**, drawing downwards the central tendon and increasing the vertical diameter of the thorax. Of the two movements the former is the more important. There has been considerable diversity of opinion regarding the action of the intercostal muscles. It is generally agreed that the external muscles elevate the ribs; it is probable that the whole of each internal muscle acts in the same way, although it has been stated by different observers that the whole internal muscle is a depressor; or that the interosseous part is a depressor, the interchondral portion of the muscle an elevator of the ribs.

FASCIÆ AND MUSCLES OF THE ABDOMINAL WALL.

The space between the margins of the bony thorax and the pelvis is filled up by a series of muscular sheets, covered externally and internally by fasciæ.

FASCIÆ.

The fasciæ of the abdominal wall are—*externally*, the superficial and deep fasciæ; *internally*, the fascia transversalis, which is continuous with the diaphragmatic, lumbar, psoas, iliac, and pelvic fasciæ, and is lined within by the **extra-peritoneal tissue.**

The **superficial fascia** of the abdomen is liable to contain a large quantity of fat. It is separated in the groin into *two layers*: a superficial fatty layer continuous over Poupart's ligament with the fascia of the front of the thigh (p. 356), and a deeper membranous layer attached to the inner half of Poupart's ligament, and more externally to the fascia lata of the thigh below Poupart's ligament. The two layers are separated by the lymphatic glands and the superficial vessels of the groin. Higher up in the abdominal wall the two layers blend together, and passing

downwards over the spermatic cord, they unite to form the fascia and dartos muscle of the scrotum. The attachment of the fascia to the groin prevents the passage into the thigh of fluid extravasated in the abdominal wall.

The **deep fascia** of the abdominal wall resembles similar fasciæ in other situations. It forms an investment for the obliquus externus muscle, and becomes thin and almost imperceptible in relation to the aponeurosis of that muscle.

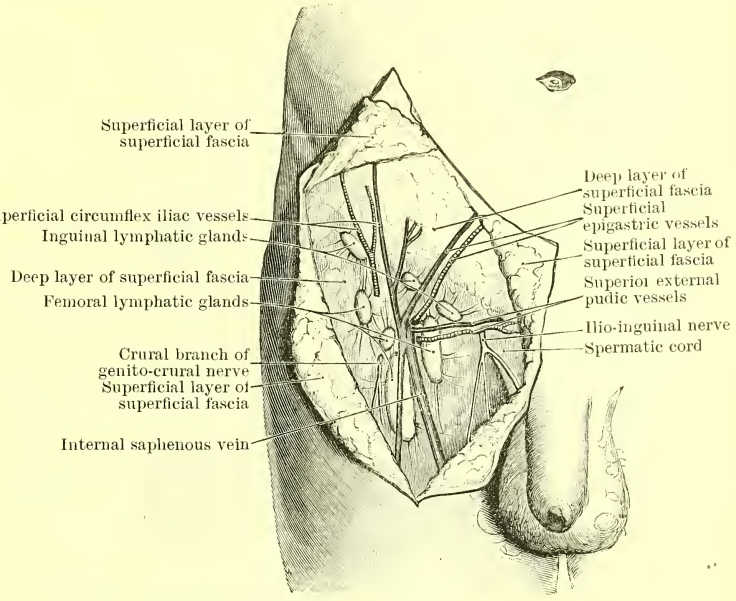


FIG. 337.—THE GROIN. STRUCTURES BETWEEN THE LAYERS OF THE SUPERFICIAL FASCIA.

The **fascial lining** of the abdominal cavity (**fascia transversalis**) consists of a continuous layer of membrane which receives different names in different parts of its extent. It covers the deep surface of the transversalis muscle, and is continuous internally (through the lumbar fascia) with the fasciæ of the quadratus lumborum and the psoas muscles. It is continuous above with the diaphragmatic fascia, and below (the iliac crest and Poupart's ligament intervening) with the fascia iliaca. Along with the last-named fascia it forms the **femoral sheath**. It is pierced by the spermatic cord or round ligament of the uterus at the internal abdominal ring, and its prolongation into the inguinal canal around the cord forms the **infundibuliform fascia**. It is lined internally by the peritoneum, from which it is separated by a layer of **extra-peritoneal tissue**.

The **extra-peritoneal tissue** is usually loaded with fat; it envelops the kidneys, ureters, suprarenal capsules, abdominal aorta and inferior vena cava and their branches, and forms sheaths for the vessels and ducts (ureter, vas deferens, etc.) It is continued upwards into the posterior mediastinum of the thorax through the aortic opening in the diaphragm, and below is in continuity with the extra-peritoneal tissue in the pelvis. It not only completely invests the kidneys and suprarenal capsules, but it also becomes interpolated between the layers of peritoneum upholding and enveloping the intestines. This tissue is absent in relation to the diaphragm, on the under surface of which there is also no fat.

THE MUSCLES OF THE ABDOMINAL WALL.

The muscles of the abdominal wall are in three series—lateral, anterior, and posterior.

The **lateral muscles** of the abdominal wall comprise the obliquus externus, obliquus internus, and transversalis abdominis.

The **obliquus externus abdominis** is a broad thin sheet of muscle, with an **origin** from the outer surfaces of the lower eight ribs, by slips which interdigitate with the serratus magnus and latissimus dorsi muscles. The muscular fibres radiate downwards and forwards, the lowest fibres passing vertically downwards. The lower and posterior part of the muscle is **inserted** directly by fleshly fibres into the outer lip of the iliac crest in its anterior half or two-thirds (Fig.

290, p. 373). The rest of the muscle is inserted into an extensive triangular aponeurosis covering the anterior abdominal wall. This aponeurosis is broader below than above; it is united with part of the aponeurosis of the obliquus internus in the upper three-fourths of its extent, to form the anterior layer of the **sheath of the rectus muscle**. It thus gains an attachment, above to the ensiform cartilage, below to the symphysis pubis, and by its intermediate fibres to the **linea alba**, a broad interlacing band of fibres about half an inch in width which occupies the middle line of the anterior abdominal wall in its whole extent, and forms the greater part of the ultimate insertion of all the lateral abdominal muscles.

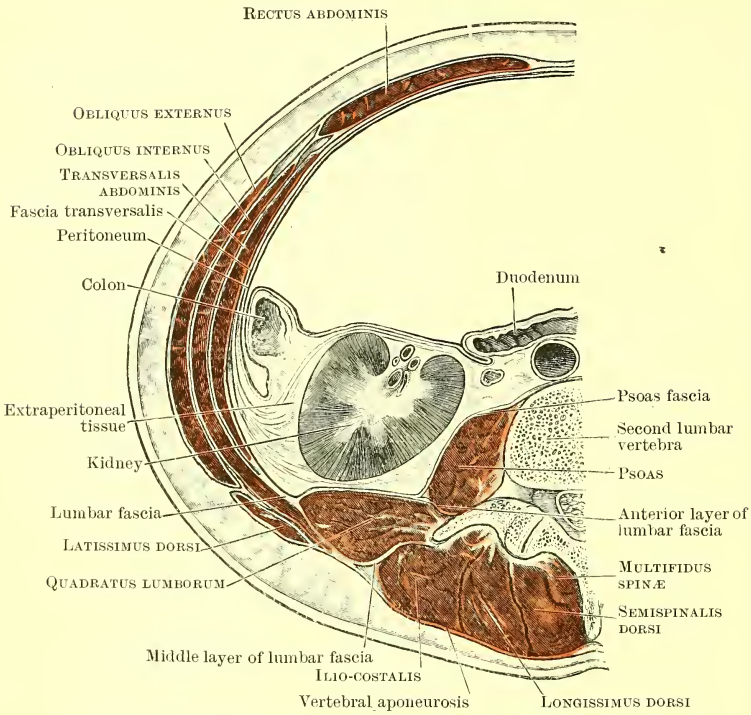


Fig. 338.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

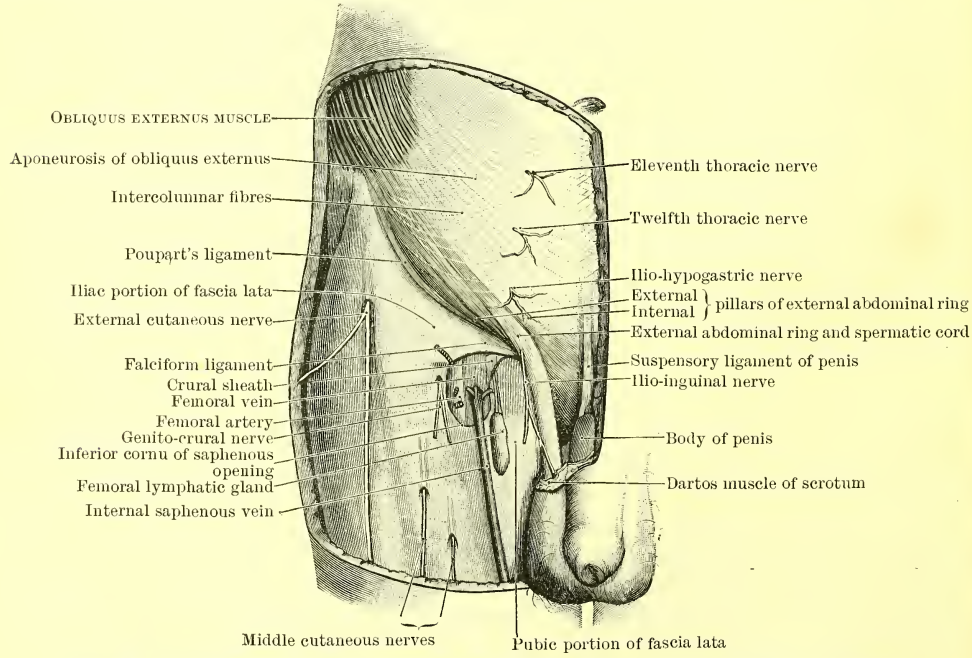


Fig. 339.—The Groin. The Structures seen on removal of the Superficial Fascia.

The upper part of the aponeurosis covers the insertion of the rectus abdominis

muscle on the chest wall, and gives origin to fibres of the pectoralis major. Below, in the groin, it gives rise to Poupart's ligament, Gimbernat's ligament, the external abdominal ring with its two pillars, the intercolumnar fascia and fibres, and the triangular fascia.

Poupart's ligament is a fascial band which extends from the anterior superior

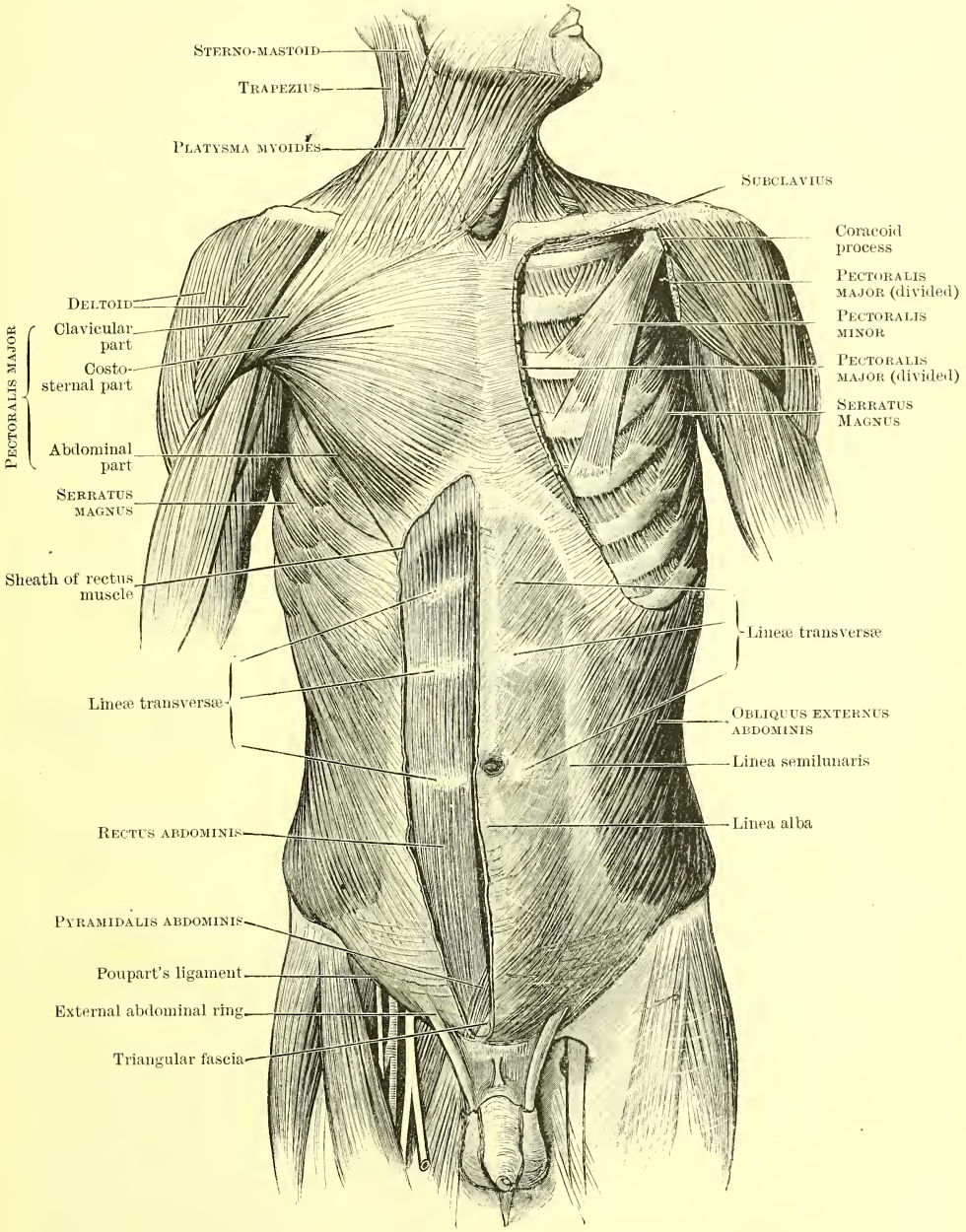


Fig. 340.—Anterior Muscles of the Trunk.

iliac spine to the spine of the pubis, arching over the iliacus, psoas, and pectineus muscles. It represents the lower limit of the aponeurosis of the obliquus externus abdominis, and gives attachment below to the fascia lata of the thigh. Its outer part affords partial origin to the deeper lateral muscles of the abdominal wall, and receives the attachment of the fascia transversalis and fascia iliaca; the inner part forms the gutter-like floor of the inguinal canal. At its inner end a triangular band of fibres is reflected horizontally backwards to the ilio-pectineal line, forming

Gimbernat's ligament, the outer edge of which limits internally the **crural ring**. The femoral vessels enclosed in the femoral sheath enter the thigh beneath Poupart's ligament, in front of the psoas muscle, and the term *superficial crural arch* is given to the part of the ligament which covers the vessels.

The **external abdominal ring**, the place of exit of an inguinal hernia, is a split in the aponeurosis of the obliquus externus, just above the spine of the pubis. It transmits the spermatic cord, or round ligament of the uterus, covered by the cremaster muscle or cremasteric fascia. The opening is of considerable extent, and its edges are drawn together by a thin fascia, strengthened superficially by a number of arched and horizontal fibres, called the **intercolumnar fibres**, which arise from Poupart's ligament and sweep inwards across the cleft in the aponeurosis.

The margins of the ring constitute its pillars. The **external pillar** is narrow, and is formed from that part of the aponeurosis which joins the pubic spine, and is continuous with the inner end of Poupart's ligament. The **internal pillar** is the part of the aponeurosis internal to the ring which is attached to the crest and symphysis of the pubis. It is flat and broad.

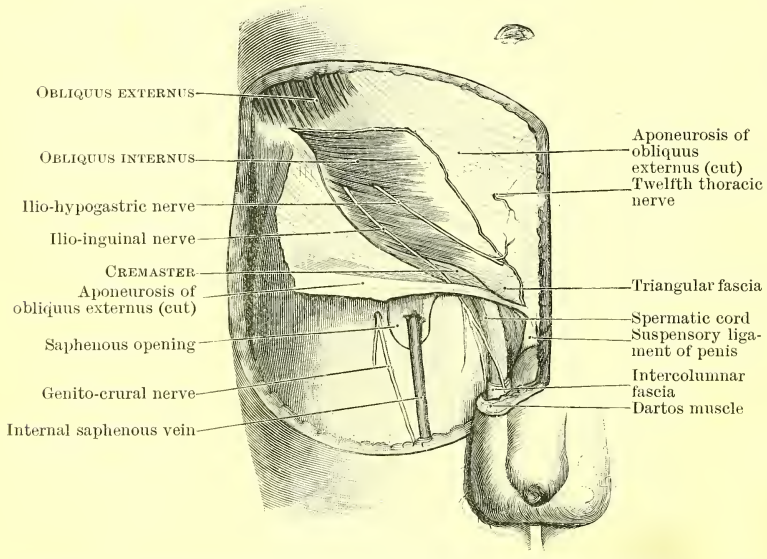


Fig. 341.—The Groin. The Structures seen on removal of part of the Obliquus Externus.

The intercolumnar fibres and the pillars of the external abdominal ring are continuous with a thin tubular sheath, the **intercolumnar** or **external spermatic fascia**, which is attached to the margins of the "ring," and forms an envelope for the spermatic cord or round ligament in their further passage beyond the abdominal wall.

The **triangular fascia**, lastly, is a triangular band of fibres placed behind the internal pillar of the external abdominal ring. It consists of fibres from the *opposite* external oblique aponeurosis, which, having traversed the linea alba, gain an insertion into the crest and spine of the pubis.

The obliquus externus muscle is superficial in almost its whole extent. It is overlapped posteriorly by the latissimus dorsi muscle, but may be separated from it just above the iliac crest by an angular interval (triangle of Petit).

The **obliquus internus abdominis**, a broad thin sheet lying between the obliquus externus and the transversalis, **arises** from (1) the lumbar fascia, (2) the anterior half of the iliac crest, and (3) the outer half of Poupart's ligament. Directed for the most part upwards and forwards, its highest fibres are **inserted** directly into the last three ribs. The rest of the fibres form an extensive aponeurosis, broader above than below, which splits along the **linea semilunaris**, to form, along with the aponeuroses of the obliquus externus and transversalis muscles, the **sheath of the rectus abdominis**, and is thereafter inserted into the seventh, eighth, and ninth costal cartilages, and into the linea alba from the ensiform cartilage to the symphysis pubis. The fibres arising from Poupart's ligament join with those of the transversalis muscle having a similar origin to form the **conjoint tendon**, which passes altogether in front of the rectus muscle, to be attached to the pubic crest and spine and to the ilio-pectineal line.

The obliquus internus is limited above by the costal arch. Its lower fibres, arching over the spermatic cord, assist in forming, externally, the anterior wall of the inguinal canal; internally, by means of the conjoint tendon, it helps to form the posterior wall of the canal.

Its lowest fibres are continued into the **cremaster muscle**, which is prolonged along the spermatic cord through the inguinal canal.

The **cremaster muscle** may be said to have an **origin** from the lower border of the obliquus internus, and from the centre of Poupart's ligament. It forms a thin sheet, enveloping the testicle and spermatic cord; its fibres are arranged in loops which arch over the cord, and are **inserted** into the fascia, and to a less extent (uppermost fibres) into the pubic spine. The muscle is more largely represented by fascia in the female, and constitutes the **cremasteric fascia.**

The **transversalis muscle** arises (1) from the under surface of the costal cartilages of the lower six ribs, inter-digitating with the origins of the diaphragm; (2) from the lumbar fascia; (3) from the anterior half of the inner lip of the iliac crest; and (4) from the outer third of Poupart's ligament. The muscular fibres

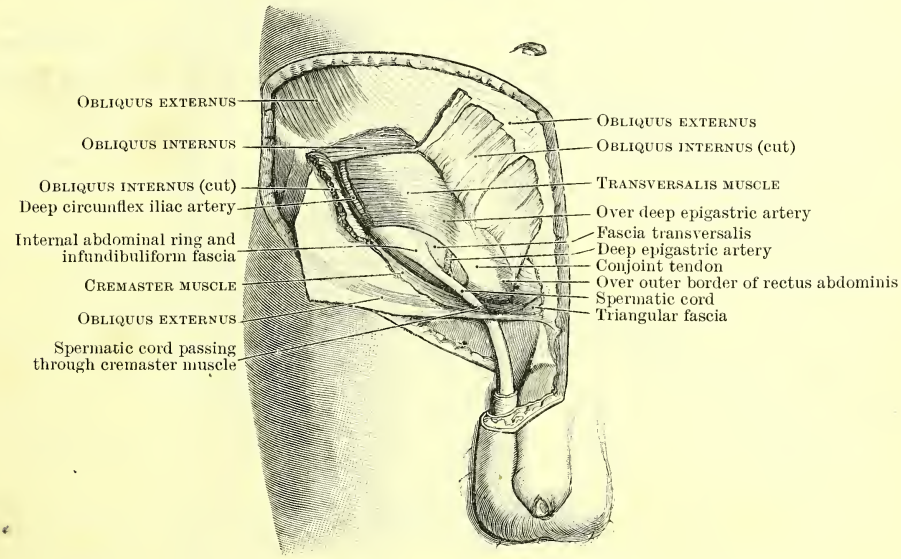


Fig. 342.—The Groin. The Structures seen on reflexion of part of the Obliquus Internus.

are directed for the most part horizontally forwards, and end in an aponeurosis which has a twofold **insertion.** (1) After forming (along with the aponeurosis of the obliquus internus) the posterior layer of the sheath of the rectus, the aponeurosis is attached to the ensiform cartilage and linea alba. (2) The lower fibres of the muscle arising from Poupart's ligament are joined by the lower part of the obliquus internus to form the larger part of the **conjoint tendon**, which passes in front of the lower part of the rectus muscle, to be inserted into the crest and spine of the pubis and the ilio-pectineal line.

The transversalis muscle is separated by the lower intercostal nerves from the obliquus internus muscle, and is lined on its deep surface by the transversalis fascia. Its lower border forms a concave edge, separated from Poupart's ligament by a lunular interval in which the transversalis fascia appears, and through which the spermatic cord emerges at the internal abdominal ring, under cover of the obliquus internus muscle and the aponeurosis of the obliquus externus.

The **anterior muscles** of the abdominal wall include the pyramidalis and rectus abdominis, enveloped by the sheath of the rectus on either side of the linea alba.

The **pyramidalis abdominis** is a small triangular muscle **arising** from the pubic crest in front of the rectus muscle (Fig. 282, p. 366). It is directed obliquely

upwards, to be **inserted** for a variable distance into the linea alba. The muscle is often absent.

The **rectus abdominis muscle** is broad and strap-like, and **arises**, by an inner and an outer head, from the symphysis and crest of the pubis (Fig. 282, p. 366). Expanding as it passes upwards, the muscle is **inserted** from within outwards into the front of the ensiform cartilage (Fig. 246, p. 322), and into the front of the seventh, sixth, and fifth costal cartilages. On its anterior surface, but not extending through the entire substance of the muscle, are three or more transverse tendinous intersections (**lineæ transversæ**), adherent to the sheath of the muscle; the lowest opposite the umbilicus, and the highest about the level of the ensiform cartilage. Enclosed in its sheath, and covered anteriorly by the pyramidalis muscle, the rectus conceals the superior and deep epigastric vessels, the terminal branches of the lower thoracic nerves (which pierce the muscle to reach the anterior abdominal wall), the fold of Douglas, and the fascia transversalis. The inner border of the muscle lies alongside the linea alba; its outer border is convex, and corresponds to the **linea semilunaris**.

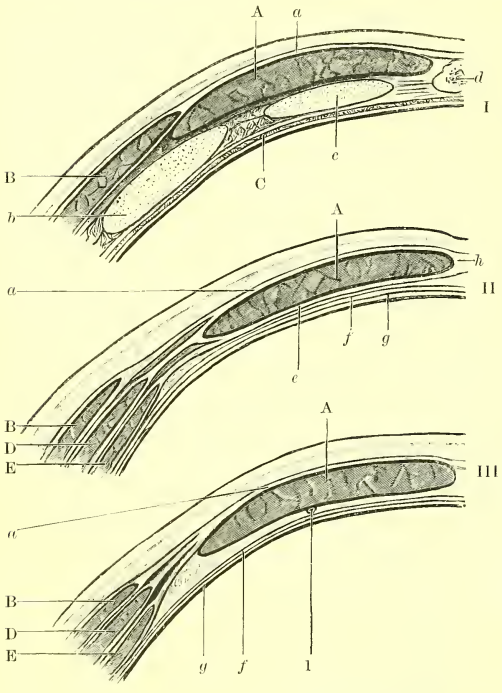


Fig. 343.—The Sheath of the Rectus Abdominis Muscle.

(I.) In the thoracic wall; (II.) In the upper three-quarters of the abdominal wall; (III.) In the lower fourth of the abdominal wall.

A, Rectus muscle; B, Obliquus externus; C, Diaphragm; D, Obliquus internus; E, Transversalis abdominis. *a*, Anterior layer of rectus sheath; *b*, Fifth costal cartilage; *c*, Sixth costal cartilage; *d*, Xiphoid cartilage; *e*, Posterior layer of rectus sheath; *f*, Transversalis fascia; *g*, Peritoneum; *h*, Linea alba. 1, Deep epigastric artery.

The **sheath of the rectus muscle** is derived from the aponeuroses of the lateral muscles of the abdominal wall, which, after enclosing the muscle, give rise in the middle line to the linea alba. At the linea semilunaris, at the outer border of the rectus muscle, the aponeurosis of the obliquus internus splits into anterior and posterior layers. The anterior layer, joined by the aponeurosis of the obliquus externus, passes in front of the rectus, and constitutes the anterior lamina of the sheath. The posterior layer, joined by the aponeurosis of the transversalis muscle, passes behind the rectus, and constitutes the posterior lamina of its sheath. This arrangement obtains in the upper three-fourths of the abdominal wall. Below the level of the iliac crest the sheath of the muscle is deficient posteriorly, and a crescentic border, the **fold of Douglas**, marks the lower limit of the posterior lamina. In consequence, the rectus in the lower fourth of the abdominal wall rests upon the fascia transversalis directly. Close examination, however, usually reveals a thin layer behind the muscle in continuity with the fold of Douglas, and merging below with the fascia transversalis. In this region the rectus is covered anteriorly by the conjoint tendon of the obliquus internus and transversalis, and by the aponeurosis of the obliquus externus, which is gradually becoming separate from the subjacent aponeurosis. The upper part of the rectus, lying on the chest wall, is only covered anteriorly by a single layer of aponeurosis derived from the obliquus externus, which in this situation is giving origin to the pectoralis major muscle.

Inguinal Canal.—The spermatic cord in the male, and the round ligament in the female, in their passage through the lower part of the abdominal wall, pass through the inguinal canal, which is bounded by these abdominal muscles. The canal begins at the *internal abdominal ring*, placed half an inch above Poupart's

ligament, and midway between the anterior superior iliac spine and the symphysis pubis. It ends at the *external abdominal ring*, placed above the spine and crest of the pubis. The *front wall* of the canal is formed by the aponeurosis of the obliquus externus, and in its outer part by the muscular fibres of the obliquus internus; the *back wall* of the canal is formed by the fascia transversalis, and in its inner part by the conjoint tendon; while the *floor* of the canal is formed by

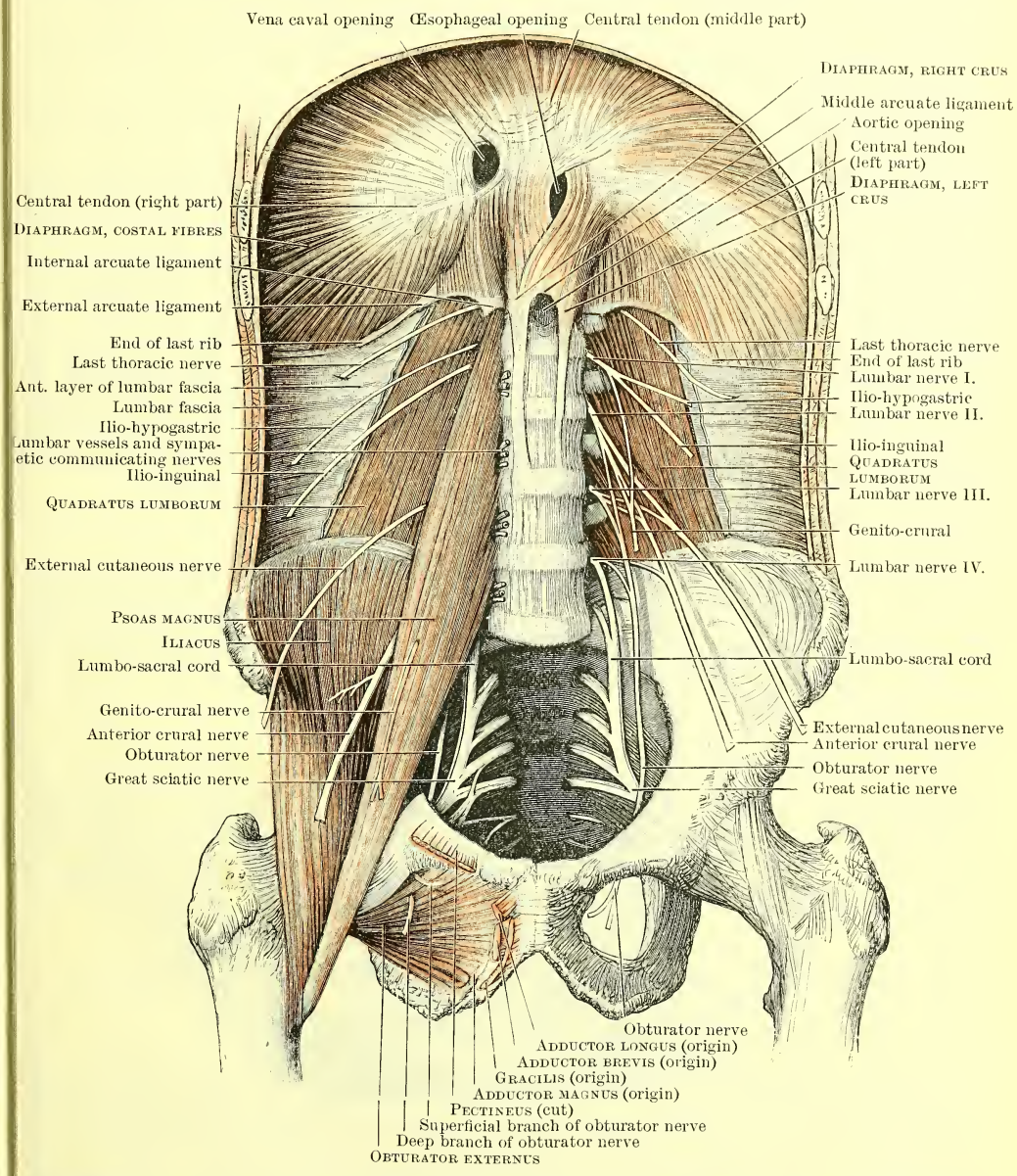


Fig. 344.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

Poupart's ligament, and in its inner part by Gimbernat's ligament. The spermatic cord, piercing the transversalis fascia, enters the inguinal canal at the internal abdominal ring, and is there invested by its *first envelope*, the **infundibuliform** or **internal spermatic fascia**, a sheath of fascia derived from the margin of the ring and continuous with the fascia transversalis. It then passes obliquely inwards, downwards, and forwards, and escapes below the lower border of the obliquus internus muscle, from which it carries off a *second investment*, partly fascial, partly muscular

—the **cremaster muscle** or **cremasteric fascia**. Continuing its course in front of the conjoint tendon, it emerges through the external abdominal ring, from the edges of which the **intercolumnar fascia** is derived, the *third* or *external investment* for the cord.

Hesselbach's triangle, bounded below by the line of Poupart's ligament, internally by the rectus abdominis muscle, and externally by the deep epigastric artery on the mesial side of the internal abdominal ring, is the site of one form of inguinal hernia. The spermatic cord passes over the base of the triangle, covered over by the aponeurosis of the obliquus externus. Behind the cord, and forming the floor of the triangle, are the fascia transversalis and the conjoint tendon of the obliquus internus and transversalis muscles.

Inguinal Hernia.—For an account of the anatomical relations of the inguinal canal to the various forms of inguinal hernia, see the section on "Applied Anatomy."

The **posterior muscles of the abdominal wall and false pelvis** include the psoas (magnus and parvus) and iliacus, described already (p. 363), and the quadratus lumborum.

The **quadratus lumborum** lies on the posterior wall of the abdomen external to the psoas, and extends between the iliac crest and the last rib. It **arises** from the posterior part of the iliac crest, from the ilio-lumbar ligament, and from the transverse processes of the lower lumbar vertebræ. It is **inserted** above into the inner part of the lower border of the last rib and the transverse processes of the upper lumbar vertebræ. It is enclosed between the anterior and middle layers of the lumbar aponeurosis (p. 391), and is placed behind the colon, kidney, and psoas muscle, in front of the multifidus spinæ and the lumbar transverse processes. Its outer border is directed obliquely upwards and inwards.

Nerve-Supply.

The nerve-supply of all the foregoing muscles except the psoas, cremaster, quadratus lumborum, and iliacus, is derived from the anterior primary divisions of the **lower six thoracic nerves**. The pyramidalis muscle is innervated by the **last thoracic nerve**. The cremaster muscle receives its supply from the **genito-crural nerve**, whilst the quadratus lumborum is innervated by the first three or four **lumbar nerves**. The psoas and iliacus muscles are supplied, directly or through the **anterior crural nerve**, from the second, third, and fourth lumbar nerves.

Actions.

Many of the actions of the above muscles have already been given in previous sections. (1) Their chief action is to retract the abdominal walls, and, by compressing the contents of the abdomen, they are powerful agents in vomiting, defæcation, micturition, parturition, and laboured expiration. (2) They are also flexors of the spine and pelvis—the muscles of both sides acting together; the spine and pelvis are laterally flexed, when one set of muscles acts alone. (3) The quadratus lumborum is a muscle of inspiration, an extensor of the spine, and a lateral flexor of the spine and pelvis.

FASCIÆ AND MUSCLES OF THE PERINEUM AND PELVIS.

FASCIÆ OF THE PERINEUM.

The **superficial fascia** of the perineum possesses certain special features. It is continuous with the superficial fascia of the abdominal wall, thigh, and buttock, and is prolonged on to the penis and scrotum. In relation to the penis, it is devoid of fat and consists only of areolar tissue. In relation to the scrotum, it is intermingled with involuntary muscular fibres, and constitutes the **dartos muscle**, which assists in suspending the testicles and corrugating the skin of the scrotum. This fascia also forms the **septum of the scrotum**, which, extending upwards, incompletely separates the two testicles and their coverings. In the female the superficial fascia takes a large share in the formation of the mons veneris and labia majora, in which a considerable quantity of fat occurs.

The fascia over the posterior part of the perineum fills up the ischio-rectal fossæ, in the form of two pads of adipose tissue, on either side of the rectum and anus. Over the tuberosities of the ischium the fat is largely replaced by bands of fibrous tissue closely adherent to the subjacent deep fascia.

The fascia in the anterior part of the perineum closely resembles the same fascia in the groin. It is divisible into a superficial fatty and a deeper membranous layer; the former continuous with the same layer in the thigh, and with the fat of the ischio-rectal fossa posteriorly. The deeper membranous layer is attached laterally to the pubic arch, posteriorly to the base of the triangular ligament, and in the middle line to the root of the penis (bulb and corpus spongiosum) by a median raphe continuous farther forwards with the septum of the scrotum mentioned above. Anteriorly the fascia is continued over the spermatic cords to the anterior abdominal wall. The importance of this fascia lies in relation to the extravasation of urine from a rupture of the urethra. By the fascial attachments the fluid is prevented from passing backwards into the ischio-rectal fossa, or laterally into the thigh. It is directed forwards into relation with the scrotum and penis, and along the spermatic cord to the anterior abdominal wall. The septum of the scrotum being incomplete, fluid extravasated on one side can pass across the middle line to the opposite half of the perineum and scrotum.

The **deep fascia** of the perineum only exists in the form of the delicate aponeuroses of the muscles.

THE MUSCLES OF THE PERINEUM.

The perineal muscles are naturally separated into a superficial and a deep set by the triangular ligament. Superficially are the sphincter ani externus, transversus

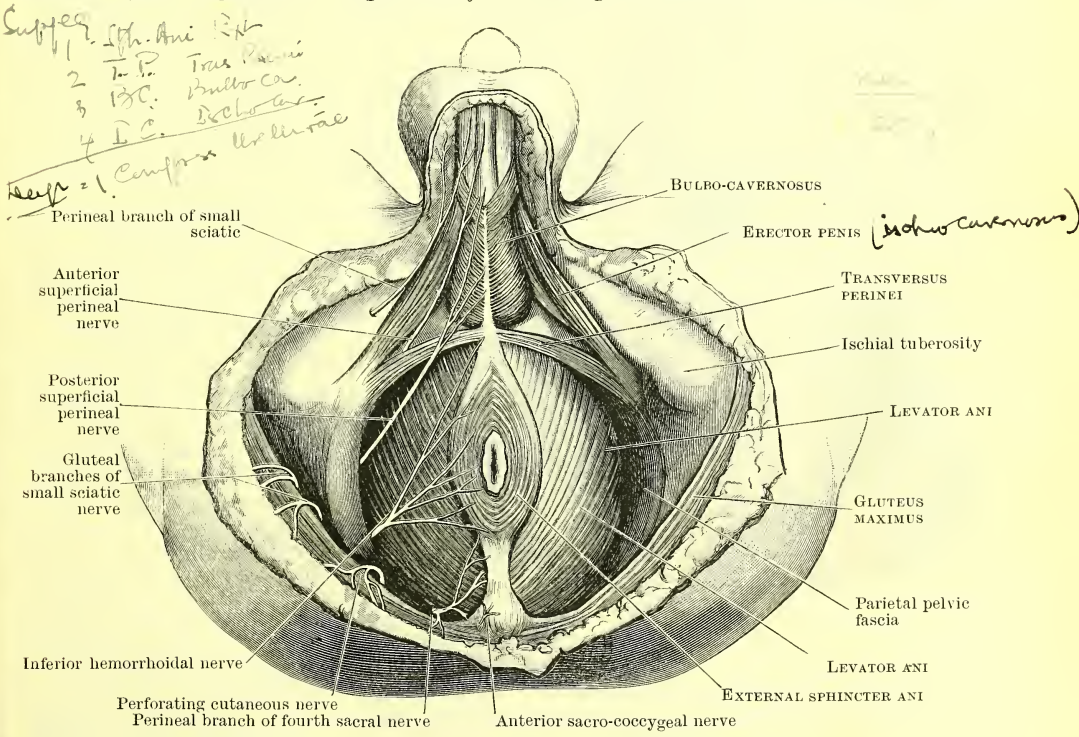


Fig. 345.—The Muscles and Nerves of the Male Perineum.

perinei superficialis, bulbo-cavernosus, and ischio-cavernosus; beneath the triangular ligament is the compressor urethræ.

Sphincter ani Externus.—This muscle is fusiform in outline, flattened, and obliquely placed around the anus and anal canal. It can be separated into three layers,—subcutaneous, superficial, and deep. (1) The most **superficial lamina** consists of subcutaneous fibres decussating behind and in front of the anus, but without bony attachments. (2) The **sphincter ani superficialis** constitutes the main portion of the muscle. It is attached posteriorly to the coccyx, and in front of the anus reaches the central point of the perineum. (3) The **deep fibres**

of the muscle form for the most part a complete sphincter for the anal canal. They are continuous with the fibres of the levator ani; they encircle the anal canal, and blend anteriorly with the central point of the perineum and the transversus perinei.

The muscle surrounds the anus, covered only by the skin, superficial fascia, and the **corrugator cutis ani** (a series of non-striated muscular fibres radiating from the anal opening). It rests on the edge of the levator ani, and forms the median boundary of the ischio-rectal fossa.

The **transversus perinei superficialis** is not always present. It consists of a more or less feeble bundle of fibres, **arising** from the ascending ramus of the ischium and the fascia over it, and from the base of the triangular ligament. It is directed inwards and forwards to be **inserted** into the central point of the perineum. It conceals the base of the triangular ligament, and has a variable relation to the superficial perineal vessels and nerves.

The **bulbo-cavernosus** (ejaculator urinæ), *in the male*, surrounds the bulb, corpus spongiosum, and root of the penis. It is sometimes separated into two parts—*posterior* (compressor bulbi), and *anterior* (compressor radicis penis). It **arises** from the central point of the perineum, and from a median raphe on the under surface of the bulb and corpus spongiosum. The muscular fibres are directed outwards and forwards, and have a triple **insertion**: from behind forwards, (1) into the under surface of the triangular ligament; (2) into the membrane covering the corpus spongiosum; and (3), after encircling the corpora cavernosa, into the fascia covering the dorsum of the penis.

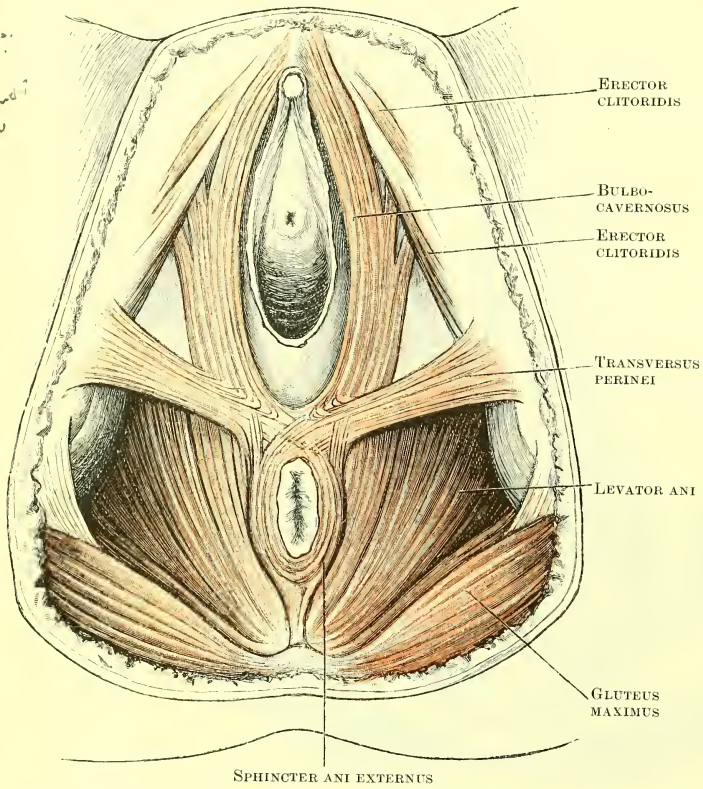


Fig. 346.—The Muscles of the Female Perineum (after Peter Thompson).

The **ischio-bulbosus**, not always present, **arises** from the ischium, and passes obliquely inwards and forwards over the bulbo-cavernosus, to be **inserted** into the raphe superficial to that muscle. It belongs to the same stratum as the transversus perinei and erector penis.

The **compressor hemispherium bulbi** is frequently absent. It consists of a thin cap-like layer of muscular fibres surrounding the extremity of the bulb under cover of the bulbo-cavernosus.

The **bulbo-cavernosus** (sphincter vaginæ), *in the female*, is separated into lateral halves by the vaginal and urethral openings. It forms two thin lateral layers covering the vaginal bulbs, and **arises** behind the vaginal orifice from the central point of the perineum. Anteriorly it is **inserted** into the root of the clitoris, some of its fibres embracing the corpora cavernosa so as to reach the dorsum of the clitoris.

The **ischio-cavernosus** (erector penis), *in the male*, covers the crus penis. It

arises from the ischial tuberosity and the great sacro-sciatic ligament, and passing forwards, is **inserted** by a fascial attachment into the under surface of the crus penis, and into the outer side and dorsal aspect of the corpus cavernosum.

The **ischio-cavernosus** (erector clitoridis), *in the female*, has a similar disposition, but is of much smaller size than in the male.

The **pubo-cavernosus** is an occasional slip **arising** from the pubic ramus, and **inserted** into the dorsum of the penis. It corresponds to the levator penis of lower animals.

The **compressor urethræ** (constrictor urethræ) constitutes the deeper muscular stratum of the perineum. It is placed on the pelvic aspect of the triangular ligament. It **arises** from the lower part of the pubic ramus, and is directed inwards, its fibres radiating so as to enclose the membranous urethra. It is **inserted** into a median raphe, partly in front of the urethra, but for the most part behind it. The fibres most intimately related to the urethra form a tubular sheath for the canal, and have no bony attachments.

The most anterior and most posterior fibres of the compressor urethræ exist sometimes as separate muscles.

The **transversus perinei profundus** consists of a bundle of fibres on either side, **arising** from the ascending ramus of the ischium just below the compressor urethræ. It is **inserted** into a median raphe continuous with that of the compressor urethræ. The muscle, in fact, constitutes a separate bundle below and behind the compressor urethræ.

The **ischio-pubicus** is a term applied to a feeble bundle of fibres which, when

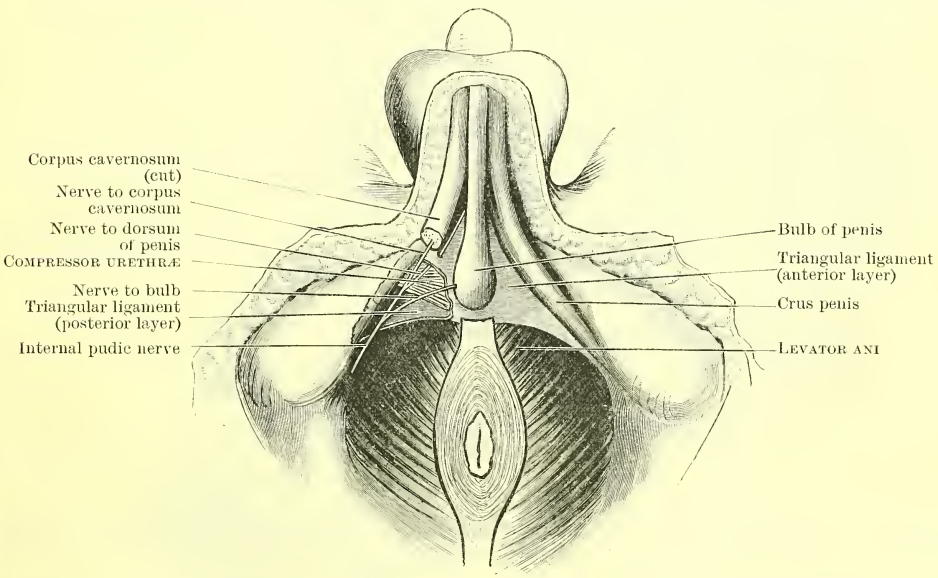


Fig. 347.—The Triangular Ligament of the Perineum, and the Termination of the Pudic Nerve.

present, lies above and in front of the compressor urethræ. It **arises** from the pubic ramus, and is **inserted** into a median raphe in front of the membranous urethra. This muscle is homologous with the **compressor venæ dorsalis penis** of lower animals.

The **compressor urethræ** *in the female* is smaller than in the male. Its insertion is modified by the relations of the urethra to the vagina. The anterior fibres are continuous with those of the opposite side in front of the urethra; the intermediate fibres pass between the urethra and vagina, and the posterior fibres are attached, along with the **transversus perinei profundus** (transversus vaginæ), into the side of the vagina.

Nerve-Supply.

The **pudic nerve** (S. 2. 3. 4.) supplies all the muscles in this group; the external sphincter through the inferior hemorrhoidal, and the others through the perineal branch of the nerve. The external sphincter is also supplied by the perineal branch of the **fourth sacral nerve.**

ACTIONS.

The **external sphincter** closes the anal canal. The **transversus perinei superficialis** draws back and fixes the central point of the perineum, assisted by the external sphincter. The **bulbo-cavernosus** of the male constricts the bulb and corpus spongiosum, and so expresses the last drops of urine or semen. In the female it acts as a feeble sphincter of the vagina. The **ischio-cavernosus** and **bulbo-cavernosus** help in erection of the penis or clitoris. The **compressor urethræ** constricts the membranous urethra, and in the female helps to flatten and fix the wall of the vagina. It also assists in causing erection of the penis or clitoris by compression of the veins in relation to it.

FASCIA OF THE PELVIS.

The pelvic basin, placed obliquely, deeper and more hollowed behind than in front, and imperfect in its bony boundaries, is to a large extent completed by ligaments. The sacro-sciatic ligaments behind, the obturator membrane laterally, and the triangular ligament in front assist in filling up its osseous deficiencies. It is almost entirely clothed internally by muscles: by the pyriformis on each side behind, the obturator internus at the side, and the compressor urethræ in contact

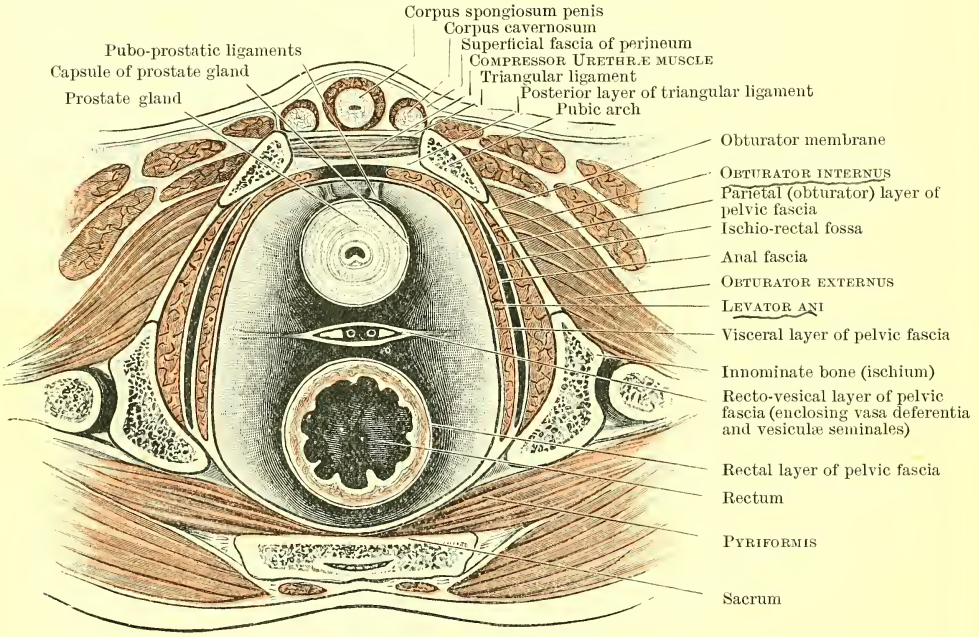


Fig. 348.—Dissection of the Pelvic Fascia from Above (diagrammatic).

with the triangular ligament in front. Indeed, the bones of the pelvis only project into the cavity in three places; the spines of the ischium project into the cavity on each side, and the pubis appears in its anterior wall.

The pelvic fascia forms a cylindrical membrane lining the wall of the pelvis, as an aponeurosis for its muscles. It is attached above and below to the inlet and outlet of the pelvis; above to the promontory of the sacrum, ilio-pectineal line, and back of the pubis; below to the coccyx, great sacro-sciatic ligament, tuber ischii, and the base of the triangular ligament. This cylindrical membrane is the **parietal pelvic fascia**; it forms the **pyriformis fascia** behind, the **obturator fascia** at the side of the pelvis, and the so-called **posterior layer** of the **triangular ligament** in front. As this fascia lines the pelvic wall it obtains attachments to the projecting bones, to the back of the pubis anteriorly, and to the spine of the ischium on each side. It is deficient in relation to the obturator groove, through which the obturator artery and nerve pass to reach the thigh.

The **white line**, a thickened band of the fascia, extends between the back of the pubis and the spine of the ischium, and roughly indicates the line of separation of the pelvic cavity from the ischio-rectal fossa. The white line serves two purposes: it gives origin to fibres of the levator ani muscle, and also to a secondary

sheet of fascia, known as the **visceral pelvic fascia**, which arches downwards and inwards across the floor of the pelvis to be connected with the pelvic viscera. This membrane is thin and unimportant behind, as it passes forwards from the lower sacral vertebræ to the rectum. It is thicker at the sides and front of the pelvis, where it forms a stout membrane concave upwards, continuous mesially with the fibrous coats of the rectum and bladder, and enveloping the prostate gland and vesiculæ seminales. At the front of the pelvis this layer extends from the back of the pubis, to which it is directly attached, to the neck of the bladder and prostate gland, and gives rise to two lateral folds—the **pubo-prostatic ligaments**, which enclose between them a hollow on the pelvic aspect of the fascia, known as the **cavum Retzii**. The lateral portion of the visceral pelvic fascia constitutes the **recto-vesical layer**, divisible into three parts—*vesical, rectal,* and between these the *recto-vesical layer,* a partition insinuated between the rectum and bladder, and enclosing the vesiculæ seminales and vasa deferentia. This visceral pelvic fascia thus forms a support for the pelvic viscera, and at the same time acts as a partition between the pelvic cavity and the perineum. It is separated from the pelvic cavity by the peritoneum and the extra-peritoneal tissue, and is in contact with the levator ani muscle on its perineal surface. The internal iliac vessels and their branches lie on the pelvic aspect of the fascia, and the parietal vessels pierce it, and are ensheathed by it as they leave the pelvis. On the other hand the spinal nerves forming the sacral plexus lie outside the fascia with one exception. The obturator nerve, after piercing the inner border of the psoas muscle and the psoas fascia, leaves the pelvis through a special hole in the pelvic wall, after traversing the extra-peritoneal tissue.

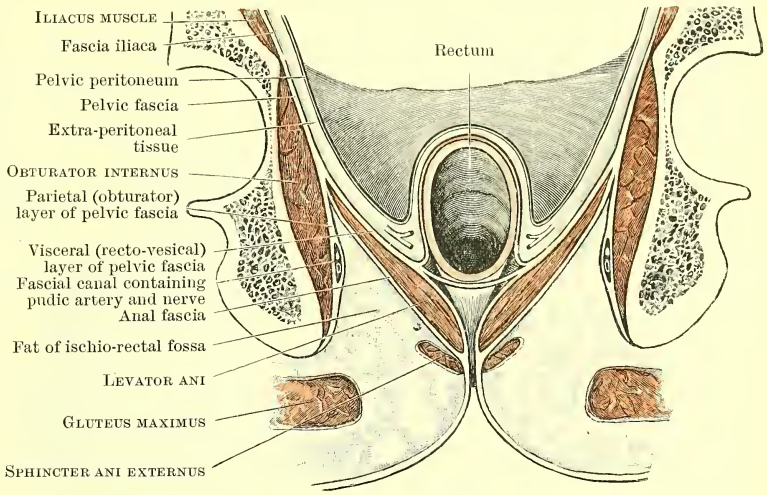


Fig. 349.—Oblique Section across the Pelvis, to show the Disposition of the Pelvic Fascia and the Boundaries of the Ischio-Rectal Fossa.

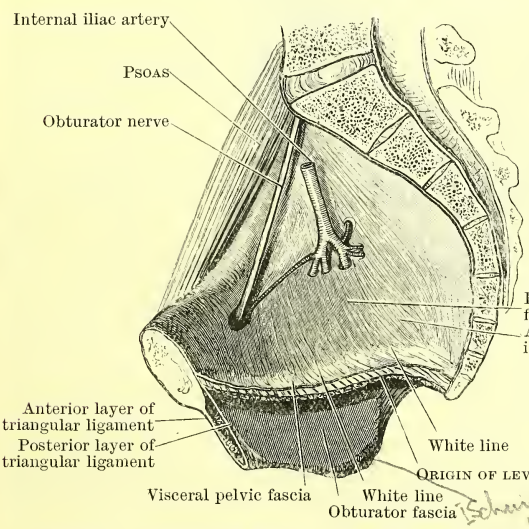


Fig. 350.—The Outer Wall of the Pelvis (Pelvic Fascia).

The *pelvic fascia in the female* only differs in slight detail from that of the male. It encloses the neck of the bladder and vagina instead of the prostate gland, and invests the lower part of the neck of the uterus instead of the vesiculæ seminales.

MUSCLES OF THE PELVIS.

The pelvic diaphragm consists of several more or less rudimentary muscular slips, constituting the levator ani and ischio-coccygeus muscles, which serve to uphold the pelvic floor, and are related to the rectum and the prostate gland or vagina.

The **levator ani arises** from (1) the back of the body of the pubis, (2) the parietal pelvic fascia above or along the *white line*, and (3) the spine of the ischium.

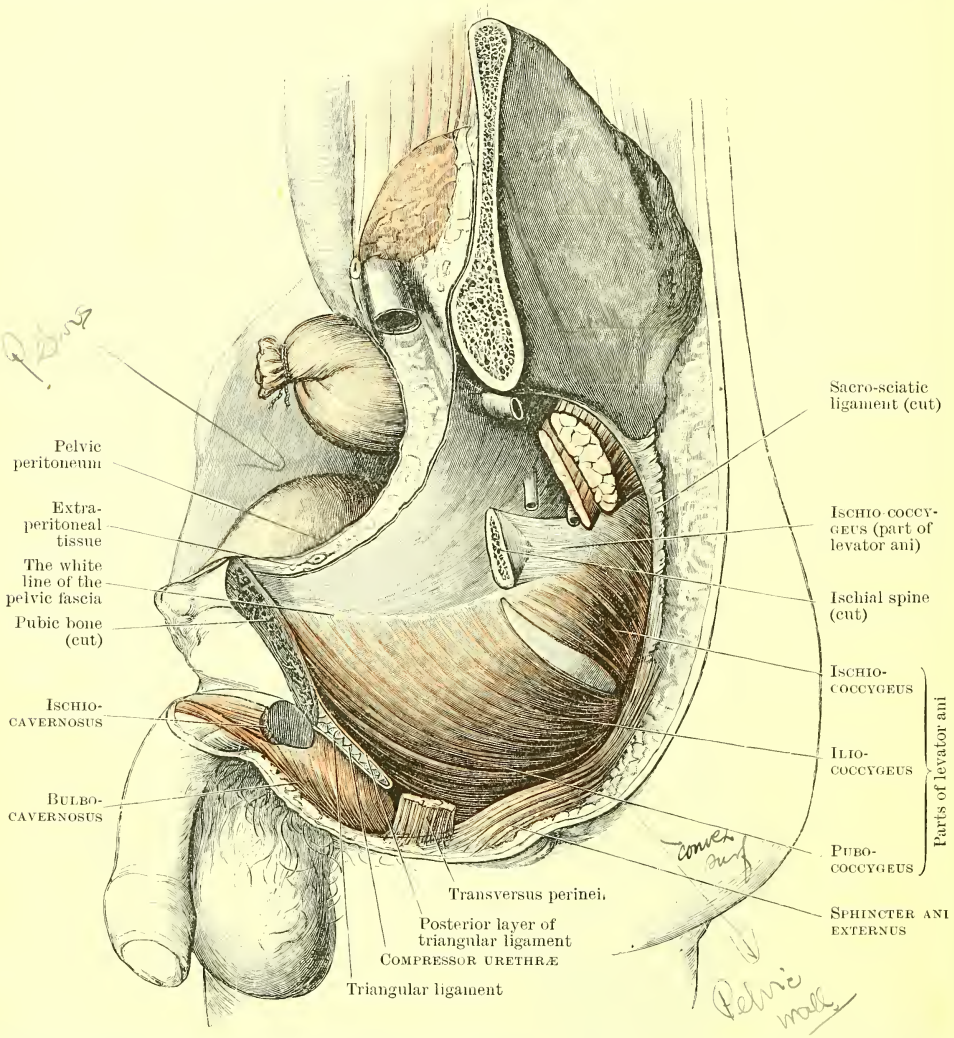


Fig. 351.—The Fascial and Muscular Wall of the Pelvis after Removal of Part of the Left Innominate Bone.

Its fibres are directed downwards and backwards, to be **inserted** into (1) the central point of the perineum, (2) the external sphincter around the anus and the ano-coccygeal raphe behind the anus, and (3) into the sides of the lower sacral and the coccygeal vertebræ.

The concave upper surface of the muscle is covered in part by the visceral pelvic fascia; in part it is in contact with the rectum behind and the prostate gland or vagina in front. The inferior convex surface of the muscle forms the inner wall of the ischio-rectal fossa. Its posterior edge is overlapped by the ischio-coccygeus; its anterior edge is in contact with the posterior layer of the triangular ligament.

The **levator ani** is divisible into four parts—pubo-rectalis, pubo-coccygeus, ilio-coccygeus, and ilio-sacralis. The **pubo-rectalis** (levator prostatæ) is the part inserted into the central point of the perineum. The **pubo-coccygeus** is the part inserted into the anus and the ano-coccygeal raphe, and the **ilio-coccygeus** and **ilio-sacralis** are represented by the fibres attached to the sacrum and coccyx. The first two are best developed; the last two series of fibres are the most rudimentary. These several parts of the muscle represent the remains of the flexor caudæ of tailed animals.

The **ischio-coccygeus** is a rudimentary muscle overlapping the posterior border of the levator ani. It **arises** from the ischial spine and the small sacro-sciatic ligament, and is **inserted** into the sides of the lower two sacral and upper two coccygeal vertebræ. The muscle is separated from the rectum by the visceral pelvic fascia, and is in contact externally with the sacro-sciatic ligaments.

Nerve-Supply.

The **levator ani** is supplied from two sources: by the perineal (muscular) branch of the pudic nerve, and, on its pelvic surface, by special branches from the third and fourth sacral nerves. The **ischio-coccygeus** is supplied on its pelvic surface by the third and fourth sacral nerves.

Actions.

(1) The levator ani and ischio-coccygeus serve to uphold and slightly raise the pelvic floor. (2) They are likewise capable of producing slight flexion of the coccyx. (3) The anterior fibres of the levator ani, in the female, sweeping round the vagina, compress its walls laterally, and along with the sphincter vaginæ, help to voluntarily diminish the lumen of the tube. (4) The same part of the muscle in the male elevates the prostate gland (levator prostatæ). (5) The chief action of the levator ani is in *defæcation*. Along with the external sphincter it acts as a sphincter of the rectum, closing the anal canal. During defæcation the muscle draws upwards the anus over the fæcal mass, and so assists in its expulsion. (6) *In parturition*, in the same way, the muscle, contracting below the descending fœtal head, retards delivery. Contracting on the fœtal head, it draws upwards the pelvic floor over the fœtus, and so assists delivery.

THE DEVELOPMENT AND MORPHOLOGY OF THE SKELETAL MUSCLES.

Our knowledge of the development and morphology of the muscular system is very incomplete. It has already been shown, in the chapter on general embryology, that the mesoblast on either side of the embryonic medullary tube separates into three main parts—the **myotome**, **nephrotome**, and **sclerotome** or **lateral plates** (somatopleure and splanchnopleure).

The **myotomes** are probably directly or indirectly the source of the striated muscles of the whole body. Each consists at first of a quadrilateral bilaminar mass, resting against the medullary tube and notochord on either side. The cleft between its two layers represents the remains of the cœlomic cavity. In the early stages of embryonic life the growth of the myotome is rapid. On its inner side masses of cells arise, which grow inwards and surround the medullary tube and notochord to form the foundation of the vertebral column. On its outer side cells appear to be given off which participate in the formation of the cutis vera. At the same time the dorsal and ventral borders of the myotome continue to extend, and present extremities (growing points) with an epithelial structure for a considerable period. *On the dorsal side* it overlies the medullary tube, and gives rise to the muscles of the back; while by its *ventral extension*, which traverses the somatopleuric mesoblast in the body wall, it produces the lateral and ventral muscles of the trunk. By an inward extension it probably gives rise also to the hypaxial muscles of the neck and loin. The cells of the inner layer of the myotome are responsible for the formation of the muscle fibres. The cells elongate in a direction parallel to the long axis of the embryo, and give rise, by fusion with the cells of neighbouring myotomes, to the columns and sheets of muscles of the back and trunk. For the most part (*e.g.* back and abdomen) the originally segmental character of the muscular elements is lost by the more or less complete fusion of adjacent myotomes. The intercostal muscles, however, are the direct derivatives of individual myotomes.

Muscles of the Limbs.—In fishes and (doubtfully) reptiles there is evidence that the myotomes are concerned in the formation of the limb-muscles by their extension into the limb-bud in a manner similar to that described for the trunk. In birds and mammals, however, in which the limb-bud arises as an undifferentiated, unsegmented mass of mesoblastic tissue, partly from the mesoblast surrounding the notochord, and partly from the somatopleuric mesoblast, the myotomes stop short at the root of each limb, and do not penetrate into its substance. Instead, the muscular elements of the limb take

origin independently as *double dorsal* and *ventral strata* of fusiform cells on the dorsal and ventral surfaces of the limb-bud. These strata are *unsegmented*; they are grouped around the skeletal elements of the limb, and they gradually become differentiated into the muscle masses and individual muscles of the limb.

Muscles of the Head.—Notwithstanding the obscurity and complexity of this

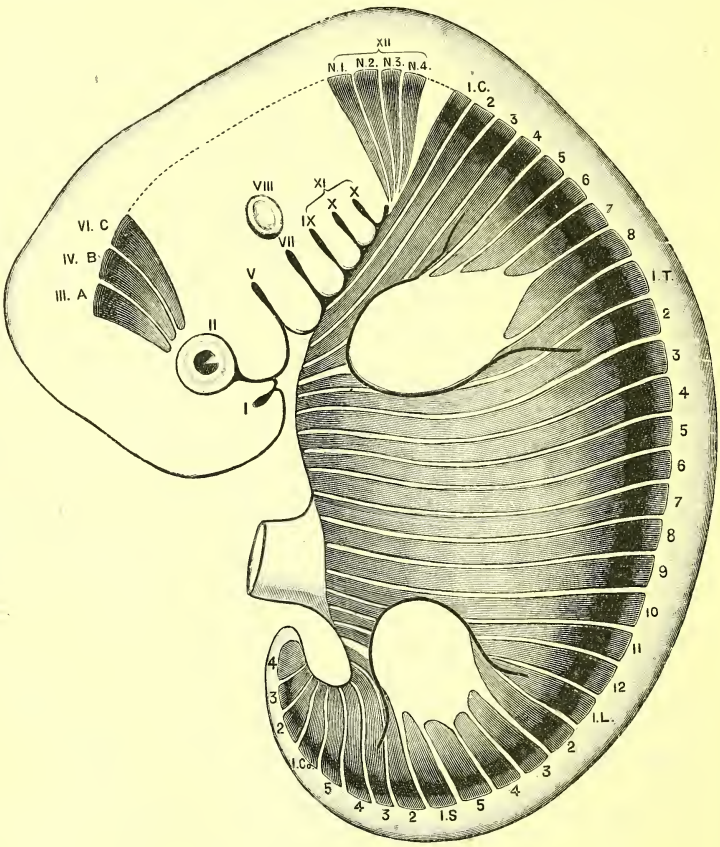


FIG. 352.

SCHEME TO ILLUSTRATE THE DISPOSITION OF THE MYOTOMES IN THE EMBRYO IN RELATION TO THE HEAD, TRUNK, AND LIMBS.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, 4, Last persisting cephalic myotomes; C., T., L., S., Co., The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves and the structures with which they may be embryologically associated.

subject, it appears certain that *at least two series* of elementary structures are concerned in the formation of the muscles of the head and face—the **cephalic myotomes** and the muscular structure of the **branchial arches.**

The number of myotomes originally existing in the region of the head is not known, although it is stated with some authority that nine is the perfect number. The *first three* are described as persisting in the form of the ocular muscles, the *last three* in relation to the muscles of the tongue, while the *three intervening myotomes* disappear.

The following table shows the possible fate of the cephalic myotomes:—

First, Superior, internal and inferior recti, obliquus inferior, levator palpebræ superioris.
Second, Obliquus superior.
Third, Rectus externus.
Fourth, *Fifth* and *Sixth*, Absent.
Seventh, *Eighth*, } Muscles of the tongue.
Ninth, *Tenth* (*first cervical*) } Muscles connecting the cranium and shoulder girdle.

The **mesoblastic tissue of the branchial arches** is probably concerned in the production of the following muscles of the face and neck:—

First (mandibular) arch . .	Muscles of mastication.
Second (hyoid) arch . . .	Platysma myoides and facial muscles. Muscles of the soft palate. Stapedius, stylo-hyoid, and digastric.
Third (thyro-hyoid) arch . .	Stylo-pharyngeus. Superior constrictor.
Fourth and Fifth (branchial) arches	Middle and inferior constrictors. Muscles of the larynx.

THE NERVOUS SYSTEM.

THE BRAIN AND SPINAL CORD, WITH THEIR MENINGES.

By D. J. Cunningham.

The nervous system connects the various parts of the body with each other and co-ordinates them into one harmonious whole. Its relatively great bulk and its extreme complexity constitute two of the most distinctive structural features of man. It consists of two parts, viz. the cerebrospinal nervous system and the sympathetic nervous system.

The **sympathetic nervous system** is composed of a chain of serially disposed ganglia, bound to each other by intervening nervous cords, and placed one on either side of the vertebral column. In addition to these gangliated cords, the sympathetic system includes certain dense plexuses of nerves and numerous scattered ganglia. The whole is most intimately connected with the cerebrospinal nervous system, and both have apparently a common developmental origin. The separation of the nervous system into the two leading subdivisions of sympathetic and cerebrospinal is therefore of a somewhat arbitrary kind.

The **cerebrospinal nervous system** consists of the brain, which very nearly completely fills the cranial cavity, and the spinal cord or spinal marrow, which only partially fills the vertebral canal. These are continuous with each other, and together constitute the cerebrospinal axis. Attached to the brain and spinal cord are the numerous nerves which bring the various parts of the body into connexion with the central nervous axis. There are thirty-one pairs of symmetrically disposed **spinal nerves** attached to the sides of the spinal cord. Each of these nerves is connected to the side of the cord by a **ventral** or **anterior** and a **dorsal** or **posterior root**, and the dorsal root is distinguished by presenting a distinct oval swelling, termed a **spinal ganglion**, on that part of its course immediately internal to the place where the two roots unite to form the **spinal nerve-trunk** (Fig. 365, p. 453).

The **cranial nerves** are twelve in number on each side, but one only (viz. the fifth or trigeminal) presents a double-rooted attachment similar to a spinal nerve Several, however, possess ganglia in every respect comparable with the ganglia on the dorsal roots of the spinal nerves. These are the fifth or trigeminal, the seventh or facial, the eighth or auditory, the ninth or glosso-pharyngeal, and the tenth or vagus cranial nerves.

CEREBROSPINAL NERVOUS SYSTEM.

The brain and spinal cord are composed of two substances which present a different appearance to the eye, and which are distinguished by the terms **white matter** and **gray matter**. The difference in colour between these two substances depends not only upon the different elements which enter into their formation, but also upon the fact that the gray matter is the more vascular of the two. The white matter is chiefly composed of nerve-fibres, whilst the essential constituents of the gray matter are nerve-cells which give origin to nerve-fibres. An all pervading matrix termed the neuroglia forms the bed in which the nerve-fibres and

nerve-cells lie, and is present both in the gray and the white matter. The elements, therefore, which constitute nervous tissue are nerve-cells, nerve-fibres, and neuroglia.

Nerve-fibres.—Nerve-fibres arranged in bundles of greater or less bulk form the nerves which pervade every part of the body. They also constitute the greater part of the brain and spinal cord. Nerve-fibres are the conducting elements of the nervous system; they serve to bring the nerve-cells into relation both with each other and with the various tissues of the body.

There are different varieties of nerve-fibres, but in all the leading and essential constituent is a delicate thread-like band, termed the **axis-cylinder.** The difference between individual fibres depends upon the fact that in some cases the axis-cylinder becomes invested by one or two coats, whilst in other cases it remains naked. When the axis-cylinder is coated on the outside by a more or less thick sheath of a fatty substance termed **myelin,** it is said to be a myelinated or medullated fibre. When the coating of myelin is absent, the fibre is termed a non-myelinated or a non-medullated fibre. A second sheath—thin, delicate, and membranous, and placed externally—may also be present in both cases. It is termed the **primitive sheath** or the **neurolemma.** From a structural point of view, therefore, four different forms of nerve-fibre may be recognised:—



FIG. 353. NERVE-FIBRE FROM A FROG (after v. Kölliker).

Non-medullated { 1. Naked axis-cylinders.
2. Axis-cylinders with primitive sheaths.
Medullated { 3. Primitive sheath absent.
4. Primitive sheath present.

Every nerve-fibre near its origin and as it approaches its termination is unprovided with sheaths of any kind, and is simply represented by a non-medullated naked axis-cylinder. The fibres of the olfactory nerves afford us an example of non-medullated fibres furnished with a primitive sheath.

Medullated fibres are present in greater quantity in the cerebro-spinal system than non-medullated fibres. Thus all the nerves attached to the brain and cord, with the exception of the olfactory and optic, are formed of medullated fibres provided with a primitive sheath; whilst the entire mass of the white substance of the brain and cord, and also the optic nerves, are formed of medullated fibres devoid of a primitive sheath.

It is important to note that the distinction between the medullated and non-medullated fibres is not one which exists throughout all stages of development. As will be presently pointed out, every fibre is a direct outgrowth from a cell, and in the first instance it is not provided with a medullary sheath. Indeed, it is not until about the fifth month of fœtal life that those fibres which are to form the white substance of the cerebrospinal axis begin to acquire their coating of myelin. Further, this coating appears in the fibres of different strands or tracts at different periods, and a knowledge of this fact has enabled the anatomist to follow out the connexions of the tracts of fibres which compose the white matter of the brain and cord.

But it may be asked: How does a nerve-fibre arise and how does it end? Every fibre is directly continuous by one extremity with a nerve-cell, whilst its opposite extremity breaks up into a number of ramifications, all of which end freely in relation to another nerve-cell, or in relation to certain tissues of the body, as, for example, to muscle-fibres or to the epithelial cells of the epidermis. The length of nerve-fibres, therefore, varies very greatly. Some fibres are short and merely bring two neighbouring nerve-cells into relation with each other: others travel long distances. Thus a fibre arising from one of the motor cells of the lower end of the spinal cord may, after leaving the cord, extend to the most outlying muscle in the sole of the foot before it reaches its destination. But even when a fibre does not leave the central axis a great length may be attained, and cells

situated in the motor area of the cortex of the cerebrum give origin to fibres which pass down to the lower end of the cord.

Physiologists classify the fibres which form the nerves into two sets, afferent and efferent. **Afferent nerve-fibres** conduct the impulse of impressions from the peripheral organs into the central nervous system; and as a change of consciousness, or, in other words, a sensation is a frequent result, these fibres are often called *sensory*. **Efferent nerve-fibres** carry impulses out from the brain and cord to peripheral organs. The majority of these fibres go to muscles and are termed *motor*; others, however, go to glands and are called *secretory*; whilst some are *inhibitory* and serve to carry impulses which restrain or check movement or secretion. As previously stated, the spinal nerves are each attached to the cord by a ventral or anterior root, and a dorsal or posterior root; the fibres composing the former are efferent; whilst the fibres of the posterior root are almost entirely afferent.

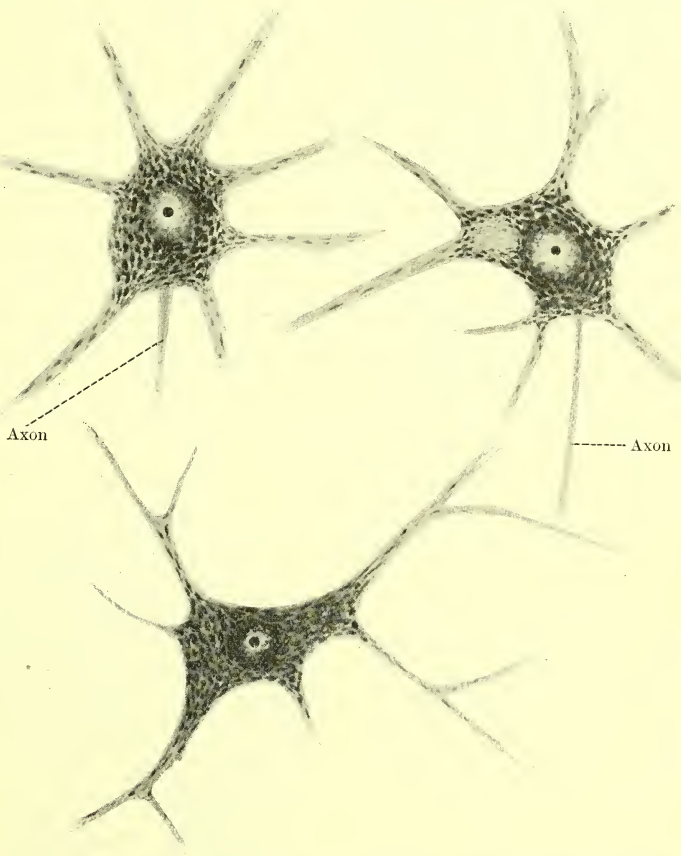


Fig. 354.—Three Nerve-Cells from the Anterior Horn of Gray Matter of the Human Spinal Cord.

Nerve-cells.—The nerve-cells constitute the active and all-essential elements of nerve-tissue. At the very start it is necessary to draw a broad distinction between the ganglionic cells, which are found in the spinal ganglia, and the cells which are so plentifully scattered through the gray matter of the brain and cord. They differ not only in their mode of origin and in their subsequent development, but also in the connexions of the nerve-fibres to which they give origin.

Nerve-cells of the Brain and Cord.—The cells in the gray matter of the cerebrospinal axis are variable both in size and form. Some are relatively large, as, for example, certain of the pyramidal cells of the cerebral cortex and the motor cells in the gray matter of the cord, which almost come within the range of unaided vision; others are exceedingly minute, and require a high power of the microscope to bring them into view. The cell consists of a protoplasmic nucleated body, from which certain processes proceed. One process is termed the **axis-cylinder process** or **axon**; and as a rule it is easily distinguished from the others, which are collectively called the **protoplasmic processes of Deiters**, or the **dendrites.**

The **axon** presents a uniform diameter and a smooth and even outline. It gives off in its course fine collateral branches, but does not suffer thereby any marked diminution in its girth. The most important point to note in connexion with the axon, however, is the fact that it becomes continuous with the axis-cylinder of a nerve-fibre. The significance of this is obvious, and will become more striking

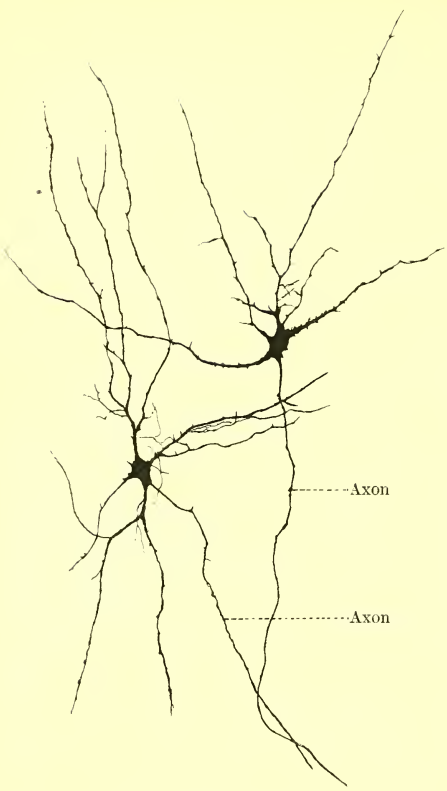


FIG. 355.—TWO MULTIPOLAR NERVE-CELLS, from a specimen prepared by the Golgi method.

when the development of the nerve-cells is studied. The axon then is simply a nerve-fibre, and in certain circumstances it assumes, as already stated, one or two investing sheaths. The axon may run its entire course within the substance of the brain or cord either for a short or a long distance, or it may emerge from the brain or cord in one of the cranial or spinal nerves as the essential part of an efferent nerve-fibre, and run a variable distance before it finally reaches the peripheral structure in relation to which it ends. The axon and the collaterals which spring from it terminate either in small button-like swellings or knobs, or more frequently in terminal arborisations, the extremities of which are free and are furnished with exceedingly small terminal varicosities. In those cases where the axon or its collaterals end within the brain or cord, some of the terminal arborisations interlace with the dendrites of nerve-cells, whilst others are twined around the bodies of other cells. In the latter case the interlacement may be so close and complete that it almost presents the appearance of an enclosing basket-work. In cases where the axon emerges from the cerebrospinal axis its terminal arborisation ends in relation to a muscle-fibre or some other tissue in the manner already referred to. In all cases, however, it would appear that the terminal branches of the axon, no matter how complicated the connexion may seem, are free, and that the connexion is simply one of contact or contiguity, and not one of continuity.

Held maintains that, although at first the terminal arborisations of an axon are quite free, in the process of growth and development they exhibit a tendency to become fused with the dendrites and even the bodies of other nerve-cells.

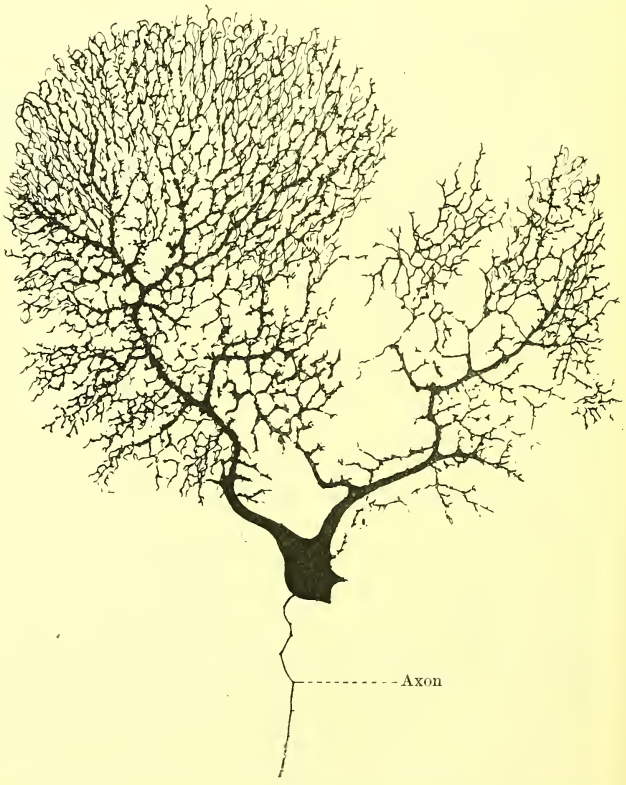


FIG. 356. — NERVE-CELL FROM CEREBELLUM (CELL OF PURKINJE) SHOWING THE BRANCHING OF THE DENDRITIC PROCESSES (from a lantern slide by Professor Symington).

The **dendrites**, or protoplasmic processes of the nerve-cell, are thicker than the axon, and present a rough-edged irregular contour. They divide into numerous branches, and these gradually, as they pass from the cell-body, become more and more attenuated until they finally end in free extremities. The branching of the dendritic processes sometimes attains a marvellous degree of complexity (Fig. 356), but except in exceptional circumstances, there is no *anastomosis* between the dendrites of neighbouring cells, or between the dendrites of the same cell. It would appear, therefore, that nothing in the shape of a network is formed by these processes.

In the chapter upon Embryology it has been shown that in the early condition of the cerebrospinal axis the brain and cord consist simply of a tube (p. 21). The wall of this tube is formed of a single layer of tall columnar neuro-epithelial cells,

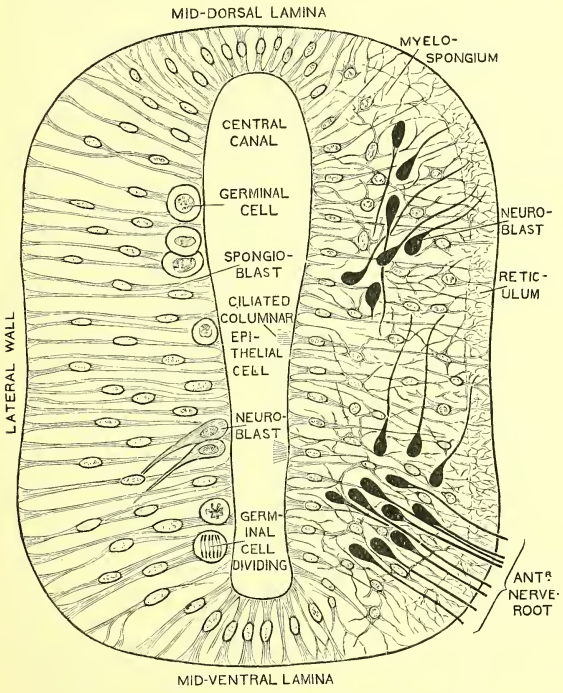


FIG. 357.—TRANSVERSE SECTION THROUGH THE EARLY NEURAL TUBE, diagrammatically represented (Alfred H. Young).

The left side of the section exhibits an earlier stage of development than the right side.

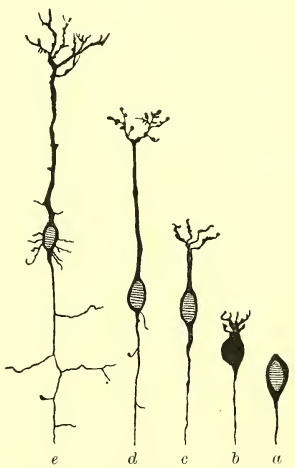


FIG. 358.—THE DEVELOPMENTAL STAGES EXHIBITED BY A PYRAMIDAL CELL OF THE BRAIN (after Ramón y Cajal).

a, Neuroblast with rudimentary axon, but no dendrites; *b* and *c*, The dendrites beginning to sprout out; *d* and *e*, Further development of the dendrites and appearance of collateral branches on the axon.

and in its deepest or most internal part large round cells make their appearance in the intervals between the epithelial columns. These new cells are termed the **germinal cells**, and from them the nerve-cells are derived. They are present in considerable numbers, and towards the fourth week of embryonic life they form an almost continuous layer. Although these cells ultimately become nerve-cells they are absolutely without processes in their early state, and therefore at this period, although there is a nervous system, there are, as His remarks, no nerves. In course of time, and as the wall of the neural tube thickens, the germinal cells begin to migrate in an outward direction. They leave the deep part of the wall of the neural tube and proceed to take up the positions they occupy in the gray matter of the cord and brain of the adult. These migrating cells assume a pyriform shape, and are termed **neuroblasts**. The drawn-out portion or stalk of the pear-shaped neuroblast represents the early axon, and this continues to grow and increase in length until it ultimately attains the terminal relations characteristic of the adult. The study of embryology presents few more remarkable phenomena than the manner in which this axon grows out, and, in the efferent nerve-fibres, emerges

from the central axis, and yet pursues its allotted path with the most unerring exactitude and precision until it ultimately reaches the nerve-cell or the peripheral tissue element with which it becomes associated. The growing point of both it and its collaterals is slightly bulbous, and it is out of this that the terminal arborisation is formed.

This conception in regard to the outgrowth of the axon in the case of the peripheral nerve-fibres has not been allowed to pass unchallenged, and it must be admitted that certain facts recently observed militate against it.

Whatever opinion may be held in regard to the developmental origin of the axis-cylinder and medullary sheath of a peripheral nerve-fibre, there is every reason for the belief that the neurolemma is mesodermic in its origin, and is therefore formed from cells outside the ectodermic neural tube. There are some who think that the axis-cylinder is secreted *in situ* by a chain of these cells, whilst others consider that the mesoblastic cells of a nerve-fibre merely constitute a cellular tube through which the growing axon worms its way to its destination, and perhaps also supply the pabulum necessary for its growth.

The dendritic processes of the nerve-cell appear at a later period than the axon. The surface of the neuroblast becomes rough and then somewhat spiny. By the growth and subdivision of these spiny projections the dendrites are formed. As His remarks, the nerve-cell is therefore the genetic centre from which all the parts of a nervous element proceed.

It must now be clear that each nerve-cell is a unit which is separate and distinct from the nerve-cells which lie around it. Further, it is obvious that it is wrong to consider the nerve-cell as something apart from the nerve-fibre. The nerve-cell with its dendrites and axon, however wide-spreading these processes may be, constitutes an independent system to which the term **neuron** is applied, and the only relation which it has with other neurons or with peripheral tissues is one of contact.

Ganglionic Nerve-Cells.—The ganglionic neurons found in the ganglia of the cranial nerves and in the ganglia on the dorsal roots of the spinal nerves have a different origin, and present many points of contrast with neurons in the gray matter of the brain and cord. As already indicated in the chapter on Embryology (p. 21) the ganglia in question are derived from the neural crest. The cells forming these ganglionic masses are somewhat oval in form, and from either extremity or pole a process grows out, and the neurons in this manner become bipolar. These processes are distinguished as central and peripheral, according to the direction which they take. The central processes grow inwards, and penetrate the wall of the neural tube. In the region of the spinal cord they form almost the whole of the fibres which enter into the composition of the dorsal roots of the spinal nerves. In the substance of the cerebrospinal axis they give off numerous collaterals, and after a course of varying extent they end, after the manner of an axon, in terminal arborisations, which enter into relationships of contact with certain nerve-cells in the cerebrospinal axis. The peripheral processes grow outwards along the path of the particular nerve with which they are associated, and they finally establish peripheral contact relations. Thus, to take one example: the majority of the fibres which go to the skin break up into fine terminal filaments, which end freely between the epithelial cells of the epidermis. The two processes of a ganglion cell, therefore, form the afferent fibres of the cerebrospinal nerves, and constitute the path along which the influence of peripheral impressions is conducted towards the brain and cord. The body of the cell is as it were interposed in the path of such impulses.

But the original bipolar character of these cells, with very few exceptions (ganglia in connexion with the auditory nerve and the bipolar nerve-cells in the olfactory mucous membrane), gradually undergoes a change which ultimately leads to their transformation into unipolar cells. This is brought about by the tendency which the cell-body has to grow to one side, viz. the side towards the surface of the ganglion (v. Lenhossek). This unilateral growth leads to a gradual approximation of the attached ends of the processes, and finally to a condition in which they appear to arise from the extremity of a short common stalk in a T-shaped manner

(Fig. 360). It is interesting to note that in certain fish the original bipolar condition of these cells is retained throughout life without change.

Both the central and peripheral processes of these ganglionic cells become the axis-cylinders of nerve-fibres, which, acquiring a medullary sheath, belong therefore to the medullated variety. From this it might very naturally be thought that the ganglionic neuron, with its two axons and no typical dendrites, is a nervous unit very different from a neuron in the gray matter of the cerebrospinal axis. It is believed by some, however (van Gehuchten and Cajal), that the peripheral process, in spite of its enclosure within a medullary sheath, and though presenting all the characters of a true axon, is in reality a dendrite. If this be the case, the morphological difference between a dendrite and an axon disappears, and van Gehuchten's functional distinction alone remains characteristic, viz. that the axon is *cellulifugal* and conducts impulses away from the cell, whilst the dendrites are *cellulipetal* and conduct impulses towards the cell.

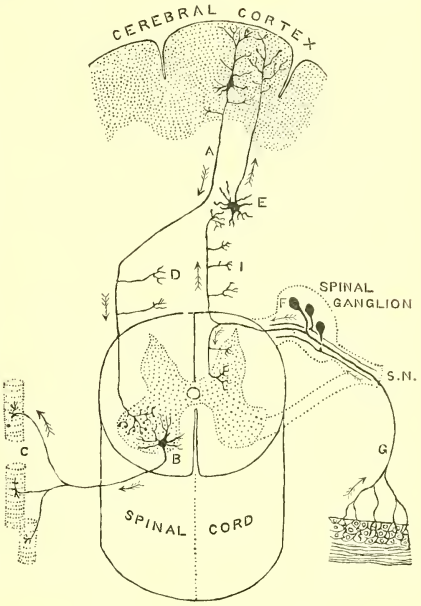


Fig. 359.—Diagram of the Connexion established by a Ganglionic and a Motor Neuron (Ramón y Cajal).

A. Fibre coming down from a pyramidal cell in the motor area of the cerebral cortex.
B. Motor cell in gray matter of spinal cord.
C. Muscle-fibres.
D. Collateral branch from the pyramidal fibre.
E. Cell in the medulla oblongata sending its axon upwards to the cerebral cortex.
F. Cells in the spinal ganglion.
G. Peripheral process of ganglionic cell ending in skin.
I. Collateral branches of central process of ganglionic cell.
S.N. Spinal nerve.

In the foregoing brief account of the elements which build up the nervous system, the neuron doctrine, as it has been enunciated by Waldeyer, has been followed. The observations of Ramón y Cajal and His form the foundation upon which this doctrine mainly rests, although it should not be forgotten that many other anatomists, amongst whom may be mentioned v. Kölliker, van Gehuchten, and v. Lenhossek, have by their investigations greatly strengthened the conception. Two primary considerations may be considered to constitute its leading support: (1) the absolute independence of the early nerve-cell or neuroblast and its processes, as was first clearly shown by His; (2) the fact that when nerve tissue is treated by the Golgi method or by the vital methylene blue method no continuity of any kind can be observed between neighbouring cells, although the processes of the cells can apparently be traced to their ultimate divisions. Further, it should be noted that the neuron doctrine receives strong support from pathological observations, and that before it assumed concrete form ideas of a somewhat similar kind were present in the minds of pathologists.

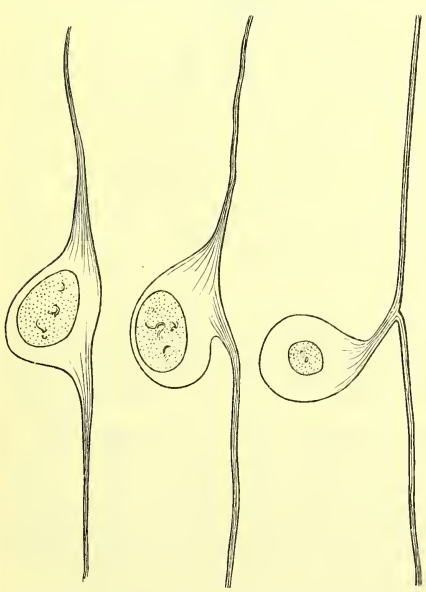


Fig. 360.—Three Stages in the Development of a Cell from a Spinal Ganglion.

Still the neuron theory is not accepted by several leading Histologists. Apáthy, Nissl, and Bethe at the present moment form a powerful combination against it. It is therefore necessary to indicate the views entertained by these observers.

More than thirty years ago Max Schultze called attention to the fact that the axis-cylinder of a nerve-fibre is composed of exceedingly fine fibrils[1] which, when traced to the cell from which the fibre takes origin, are there seen to enter the cell-body and spread out within it. By more delicate methods of research, Apáthy and Bethe have been able to place this early observation of Schultze beyond the realm of doubt. Apáthy, who worked chiefly at the invertebrate nervous system, not only traced the neuro-fibrillæ through the cell-body but

[1] It may be mentioned that Remak, the discoverer of the axis-cylinder in 1838, stated that it was finely striated in the longitudinal direction.

into all its processes, and he believes that he has been able to follow them beyond these into a delicate fibrillar interlacement which constitutes a bond of union between all the nerve-cells of the nervous system. Bethe's observations have been carried out in vertebrates. Two illustrations from his book are reproduced in Fig. 361. The cell represented in A is from the gray matter of the anterior horn of the human spinal cord, and the relation presented by the neuro-fibrils within the cell and to its various processes are very clearly depicted. The axon appears to receive a contribution of neuro-fibrillæ from all the dendritic processes; this, according to Bethe, is characteristic of the great majority of nerve-cells. In the cells indicated by the letter B, which are from the cerebral cortex of man, it will be noticed that the axons as they leave the cell become exceedingly fine and delicate, and the neuro-fibrillæ which compose them are so closely packed together that all trace of their individual existence disappears. When the medullary sheath is assumed by the fibre the neuro-fibrillæ of the axis-cylinder again become apparent.

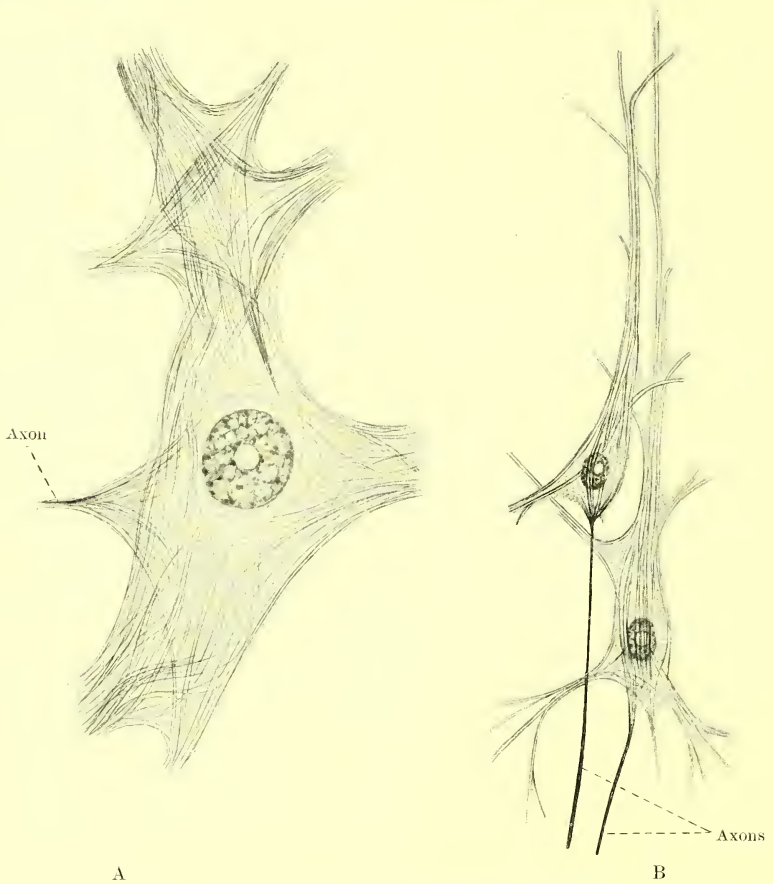


Fig. 361.—Nerve Cells as depicted by Bethe.

A, A cell from the anterior horn of gray matter of the spinal cord of man.
B, Two cells from the human cerebral cortex.

In vertebrates Bethe has not been able to trace the neuro-fibrils into an all-pervading fibrillar network such as Apáthy has described as binding the various nerve elements together in the invertebrates, but he has followed them into the finest of the dendritic branchings, and he assumes that the connecting network exists in the higher as well as in the lower members of the animal kingdom.

This conception of the structure of the axon renders the giving off by the nerve-fibre of collateral branches and also its terminal splitting or arborisation, matters which can be the more easily understood.

On the strength of the observations detailed above, Apáthy, Bethe, and Nissl, all of whom are authorities who deserve the highest degree of attention, have assailed the neuron theory. Apáthy has advanced the hypothesis that the all-pervading fibrillar interlacement, which streams continuously throughout the whole nervous system, and is found not only in the cell and its processes but also in the form of a connecting network outside the cells, is the essential part of the nervous system and not the so-called independent neurons of the neuron theory. It is also contended that axons or axis-cylinders may arise in two ways: (1) directly from the nerve-cells; (2) indirectly from the neuro-fibrillar network between the nerve-cells.

In a striking address recently delivered by Professor Waldeyer to the Royal Society of Edin-

burgh the essential points of the neuron doctrine were vigorously maintained and several new preparations by Ramón y Cajal and Beilschowsky were demonstrated. In the latter the neuro-fibrillæ were seen to enter the cell-body, spread out and break up into a plexus within it, but none could be detected pursuing an uninterrupted course right through the cell and then passing out from it.

As Edinger remarks, investigation in the immediate future will be largely concerned in the attempt to further elucidate the following questions: (1) Are the connexions between neurons merely those of contact? (2) Do the fibres which proceed from one cell fuse with the constituent parts of another neuron? (3) Do the neuro-fibrillæ form an inter-connecting network between the nerve-cells, and do axons or axis-cylinders arise from such a network? It is questionable even if the last two of these queries are answered more or less in the affirmative whether it will be necessary to abandon the essential points in the neuron theory.

Since the foregoing has been printed an instructive monograph on the subject has been published by Professor Gustaf Retzius ("Punktsubstanz 'Nervöses Grau' und Neuronenlehre," *Biologische Untersuchungen*, Neue Folge, xii.).

Neuroglia.—The neuroglia is the supporting tissue of the cerebrospinal axis. It may be considered to include two different forms of tissue, viz. the lining ependymal cells and the neuroglia proper. We place these under the one heading, seeing that in all probability they both have a common developmental origin.

The **ependymal cells** are the columnar epithelial cells which line the central canal of the spinal cord and the ventricles of the brain. In the embryonic condition a process from the deep extremity of each cell traverses the entire thickness of the neural wall and reaches the surface. It is not known whether this process exists in the adult.

The **neuroglia proper** is present in both the white and the gray matter of the cerebrospinal axis. It constitutes an all-pervading basis substance, in which the various nerve elements are embedded in such a way that they are all bound together into a consistent mass and are yet all severally isolated from each other. Neuroglia consists of cells and fine filaments. The fibrils are present in enormous numbers, and by their interlacements they constitute what appears to be a fine feltwork. At the points where the fibrils intercross may be seen the flattened glial cells. Whilst the neuroglia is for the most part intimately intermixed with the nerve elements, there are in both brain and cord certain localities where it is spread out in more or less pure layers. Thus upon the surface of the brain and of the spinal cord there is such a layer; likewise beneath the epithelial lining of the central canal and of the cavities of the brain there is a thin stratum of neuroglia.

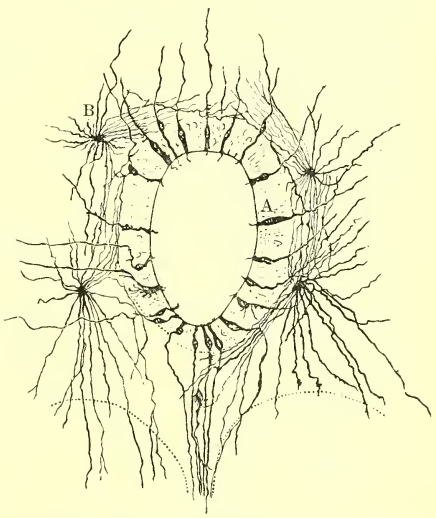


FIG. 362. — SECTION THROUGH THE CENTRAL CANAL OF THE SPINAL CORD OF A HUMAN EMBRYO, SHOWING EPENDYMAL AND NEUROGLIAL CELLS (after v. Lenhossek).
A, Ependymal cell. B, Neuroglial cell.

The ependymal cells are derived from the original neuro-epithelial cells of the early neural tube, and in all probability the neuroglia proper has a similar origin. They both, therefore, are products of the ectoderm.

Summary.—1. The cerebrospinal nervous system is composed of two parts, viz. (*a*) a **medullary part**, consisting of the brain and spinal cord, with the efferent nerve-fibres which pass out from them; (*b*) the **ganglionic part**, with the afferent nerve-fibres.

2. Each of these parts has a different origin and is composed of neurons which possess characteristic features.

3. The ganglionic neurons are derived from the primitive cells of the neural crest, and have each one process which divides into two. Of these the central division enters the cerebrospinal axis and probably represents the axon, whilst the peripheral division, which becomes connected with a peripheral part, may provisionally be regarded as a dendrite. The central fibres from the ganglionic cells

in the region of the cord form the dorsal or posterior roots of the spinal nerves. These roots have thus an origin outside the cord, and grow into its substance in the process of development in the same manner that the roots of a plant strike into the soil.

4. The cerebrospinal neurons are derived from the germinal cells in the wall of the early neural tube. Certain of these furnish efferent nerve-fibres, which issue from the cord in separate bundles termed the anterior or ventral roots of the spinal nerves. In the case of the cranial nerves, however, with the exception of the trigeminal and facial nerves, the efferent fibres are not thus separated from the afferent fibres at their attachment to the brain.

5. The brain and cord when studied by the naked eye are seen to be composed of white matter and gray matter. The white matter forms very nearly two-thirds of the entire cerebrospinal axis. It is composed of medullated nerve-fibres embedded in neuroglial tissue. The gray matter is composed of nerve-cells with their dendrites and axons. Some of the axons are in the form of naked axis cylinders, whilst others have a coating of medulla. Intimately intermixed with these parts is the neuroglia, which isolates them more or less completely from each other.

SPINAL CORD.

The **spinal cord** is that part of the cerebrospinal axis which occupies the upper two-thirds of the spinal canal of the vertebral column. It is an elongated cylindrical structure, slightly flattened in front and behind, which extends from the margin of the foramen magnum to the level of the lower border of the body of the first lumbar vertebra or to the upper border of the body of the second lumbar vertebra. Its average length in the male is 45 cm. and in the female 43 cm.

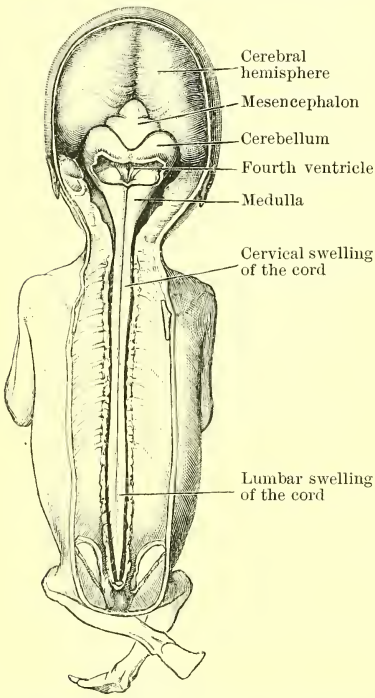


Fig. 363.—Human Fœtus in the Third Month of Development, with the Brain and Spinal Cord exposed from behind.

A considerable amount of variation within certain limits (viz. the mid-point of the body of the last dorsal vertebra and the upper border of the body of the third lumbar vertebra) is observed in different individuals as to the precise level at which the spinal cord ends inferiorly, and in the female there would appear to be a tendency for the cord to reach a slightly lower point in the canal than in the male. Further, the relation presented by the spinal cord to the vertebral column differs in a marked degree in the fœtus and infant at different periods of development. Up to the third month of intrauterine life the cord occupies the entire length of the spinal canal; it extends downwards to the lowest limit of the canal. But from this time on, as growth proceeds, the vertebral column lengthens at a more rapid rate than the cord. The spinal cord, therefore, has the appearance of shrinking in an upward direction within its canal, and at birth its lower end is usually found to be opposite the body of the third lumbar vertebra.

The attitude assumed by the individual affects to a small degree the position of the lower end of the cord. Thus, when the trunk is bent well forwards, it is noticed that the terminal part of the cord rises slightly within its bony canal.

At the margin of the foramen magnum the spinal cord becomes continuous with the medulla oblongata of the brain, whilst below, it tapers rapidly to a point and forms a conical extremity termed the **conus medullaris**. From the end of the conus medullaris a slender glistening thread is prolonged downwards within the spinal canal, and finally anchors the spinal cord to the back of the coccyx. This prolongation receives the name of the **filum**

terminale. The diameter of the cord is very much shorter than that of the spinal canal within which it lies. A wide interval is left between its surface and the walls of its canal, and this excess of space is clearly a provision for allowing free movement of the vertebral column without producing any jarring contact between the delicate spinal cord and the surrounding bones.

Three protective membranes are wrapped around the cord. From within outwards these are termed (1) the pia mater, (2) the arachnoid mater, and (3) the dura mater. The **pia mater** is a fibrous membrane which forms the immediate investment. It is closely applied to the cord, and from its deep surface numerous fine septa penetrate into the substance of the cord. The **arachnoid mater** is an exceedingly delicate transparent membrane which is loosely wrapped around the cord so as to leave a considerable interval, termed the subarachnoid space, between itself and the pia mater, in which there is always a varying amount of cerebro-spinal fluid. Outside the arachnoid mater, the **dura mater** forms a wide, dense, fibrous, tubular sheath, which extends downwards within the spinal canal for a considerable distance beyond the conical extremity of the cord. The spinal cord is suspended within its sheath or *theca* of dura mater by two lateral wing-like ligaments, termed the **ligamenta denticulata.** These extend outwards from the sides of the cord and are attached by a series of pointed or tooth-like processes to the inner surface of the theca of dura mater. Between the wall of the spinal canal and the dura mater there is a narrow interval, which is filled up by soft areolo-fatty tissue and numerous thin-walled veins arranged in a plexiform manner.

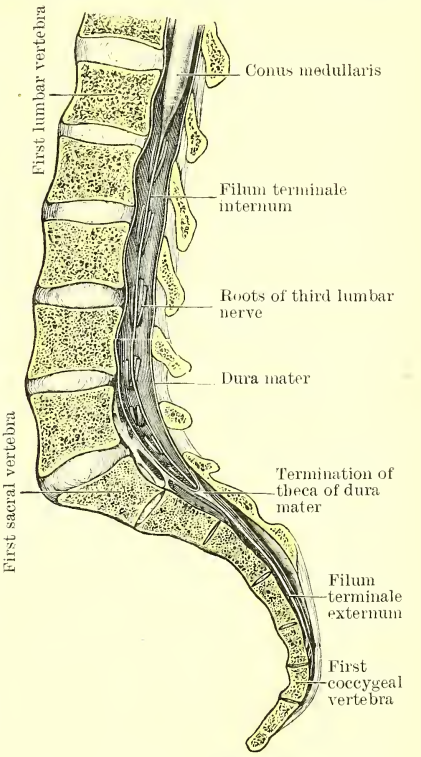


FIG. 364.—THE CONUS MEDULLARIS AND THE FILUM TERMINALE EXPOSED WITHIN THE SPINAL CANAL.

Thirty-one pairs of spinal nerves arise from the sides of the spinal cord. These are classified into eight cervical, twelve

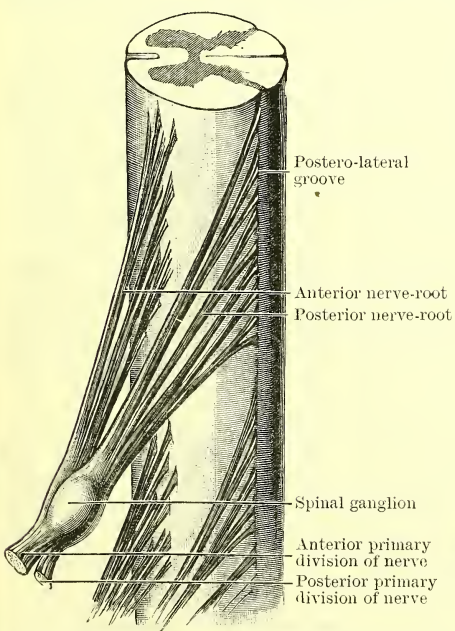


FIG. 365.—THE ROOTS OF ORIGIN OF THE SEVENTH DORSAL NERVE (semi-diagrammatic).

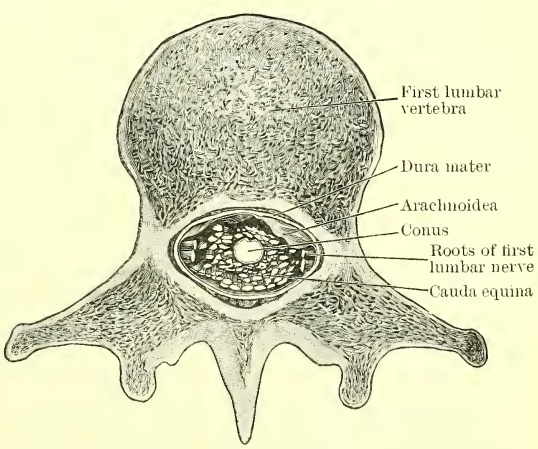


FIG. 366.—SECTION THROUGH THE CONUS MEDULLARIS AND THE CAUDA EQUINA AS THEY LIE IN THE SPINAL CANAL.

dorsal, five lumbar, five sacral, and one coccygeal; and according to the attachments of these groups of nerves the spinal cord is arbitrarily subdivided into cervical, dorsal, lumbar, and sacral regions. In employing these terms, therefore, for different districts of the cord, it must be understood that the regions are determined by the nerve attachments, and not by any direct relationship between these parts of the cord and the sections of the vertebral column which bear the same names.

Each spinal nerve is attached to the cord by a ventral and a dorsal root, and as these are traced to their central attachments they are seen to break up into a number of separate nerve fascicles or bundles, which spread out, in some cases very widely from each other, as they approach the side of the cord (Fig. 365). Each pair of nerves is therefore attached to a portion of spinal cord of some length, and such a portion, with its pair of nerves, receives the name of a "segment of the spinal cord." It must be clearly understood, however, that, in so far as the surface of the cord is concerned, there is absolutely no means of marking off one segment from another, except by the nerve attachments.

In the cervical and lumbar regions of the cord the nerve-roots are somewhat crowded together, so that little or no interval is left between the adjoining root fascicles of neighbouring nerves. In the dorsal region, however, distinct intervals may be observed, and the root fascicles are more loosely arranged. From this, it will be evident that the cord segments in different parts of the cord are not of equal length. In the cervical region the segments measure about 12 mm. in length, in the dorsal region from 20 to 24 mm., and in the lumbar region about 10 mm. The number of fascicles which attach the different nerve-roots to the cord is very different in different nerves, and is not necessarily the same in the same nerve-root in different individuals.

Owing to the great difference which exists between the length of the spinal cord and the length of the vertebral column, the farther we pass down the greater the distance becomes between the attachment of the various nerve-roots to the cord and the invertebral foramina through which the corresponding nerves leave the spinal canal. The lower nerve-roots, therefore, have to traverse the spinal canal for a considerable distance before they reach their apertures of emergence. It thus happens that the nerve-roots which spring from the lumbar and sacral regions of the cord attain a very great length and descend vertically in the lower part of the spinal canal in a bunch or leash, in the midst of which lie the conus medullaris and the filum terminale. This great bundle of nerve-roots receives the appropriate name of the **cauda equina**.

Enlargements of the Cord.—Throughout the greater part of the dorsal region, the spinal cord presents a uniform girth and a very nearly circular outline when seen in transverse section. In the cervical and lumbar regions, however, it shows marked swellings. The **cervical enlargement** (intumescentia cervicalis) is the more evident of the two. It begins very gradually at the upper end of the cord, attains its greatest breadth (12 to 14 mm.) opposite the fifth or sixth cervical vertebra, and finally subsides opposite the second dorsal vertebra. To this portion of the cord are attached the great nerves which supply the upper limbs. The **lumbar enlargement** (intumescentia lumbalis) begins at the level of the tenth dorsal vertebra, and acquires its maximum transverse diameter (11 to 13 mm.) opposite the last dorsal vertebra. Below, it rapidly tapers away into the conus medullaris. To the lumbar enlargement are attached the great nerves of the lower limbs.

These enlargements of the cord are associated with the outgrowth of the limbs. In the earlier developmental stages of the spinal cord they are not present, and they only take form as the limbs become developed. In the lower mammalia their size corresponds with the degree of development of the limbs. Thus, in the long-armed orang and gibbon, the cervical swelling stands out with a remarkable degree of prominence. It is, however, interesting to note that although in the cetacea there are no visible hind-limbs, there is nevertheless a well-marked lumbar enlargement of the cord.

Fissures and Furrows of the Cord.—When cross-sections of the spinal cord are made, it is seen to be a bilateral structure which is partially subdivided into a right and left half by two median clefts—one upon the anterior and the other upon the posterior aspect. These clefts are termed the antero-median and the postero-median fissures, and they extend along the entire length of the cord. At the same

time it must be noted that these two median clefts present many points of difference. The **antero-median fissure** (fissura mediana anterior) is for the greater part of its length much shallower than the postero-median fissure. In the cervical and dorsal regions it only penetrates for a distance corresponding to somewhat less than a third of the antero-posterior diameter of the cord. Further, the antero-median cleft is much the wider and more apparent of the two, and the pia mater dips down into it and forms a fold or reduplication within it. The **postero-median fissure** (fissura mediana posterior) in the cervical and dorsal regions penetrates into the cord until it reaches a point somewhat beyond its centre. It is extremely narrow, and contains a single septum which is derived from ependymal and neuroglial elements, and is intimately connected with the adjacent sides of the two halves of the cord, between which it intervenes. The pia mater, which invests the surface of the cord, passes continuously over the postero-median fissure and sends no prolongation of any kind into it. In the lumbar region of the cord the postero-median fissure becomes shallower, whilst the antero-median fissure deepens, and ultimately in the lower part of the cord the two fissures present a very nearly equal depth.

The two halves of the cord, which are marked off from each other by the median fissures, may show trifling differences in the arrangement of the parts which compose them; but to all intents and purposes they are symmetrical. They are joined together by a more or less broad band or commissure, which intervenes between the two median fissures.

An inspection of the surface of each lateral half of the cord brings into view a longitudinal groove or furrow, at some little distance from the postero-median cleft, which extends along the whole length of the cord. Along the bottom of this groove the fascicles of the posterior nerve-roots enter the cord in accurate linear order. It is called the **postero-lateral sulcus** (sulcus lateralis posterior). There is no corresponding furrow on the forepart of each lateral half of the cord in connexion with the emergence of the fascicles of the anterior nerve-roots. These fascicles emerge irregularly over a broad strip of the surface of the cord, which corresponds in its width to the thickness of the subjacent extremity of the anterior horn of gray matter.

The postero-lateral groove subdivides each lateral half of the cord into a small **posterior column** (funiculus posterior) and a much larger **antero-lateral column**, and it is customary to arbitrarily map off the latter into a **lateral column** (funiculus lateralis) and an **anterior column** (funiculus anterior) by a line corresponding to the emergence of the outermost fascicles of the anterior nerve-roots.

In the cervical region a distinct longitudinal groove may be observed on the surface of the posterior column. It is placed rather nearer to the postero-median than to the postero-lateral furrow, and as it is traced down into the dorsal region it gradually becomes indistinct and finally disappears. This is called the **posterior paramedian groove**, and it marks on the surface the position of a septum of pia mater which dips into the cord and subdivides the posterior column into an outer part, termed the **funiculus cuneatus** or the **column of Burdach**, and an inner portion, which receives the name of the **funiculus gracilis** or the **column of Goll**.

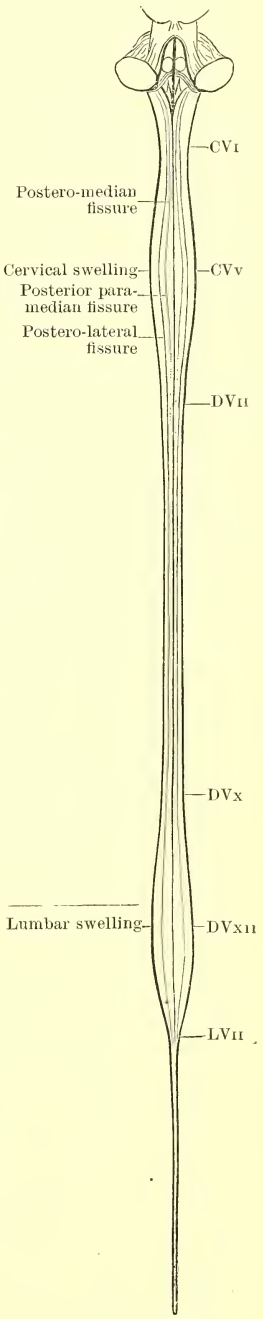


FIG. 367.—DIAGRAM OF THE SPINAL CORD AS SEEN FROM BEHIND.

CVI shows the level of the 1st cervical vertebra; CVv of the 5th cervical vertebra; DVII of the 2nd dorsal vertebra; DVx of the 10th dorsal vertebra; DVXII of the 12th dorsal vertebra; LVII of the 2nd lumbar vertebra.

Internal Structure of the Spinal Cord.

The spinal cord is composed of a central core of gray matter thickly coated on the outside by white matter. At only one spot does the gray matter come close to the surface, viz. at the bottom of the postero-lateral groove.

Gray Matter of the Cord.—The gray matter in the interior of the cord has the form of a fluted column, but it is customary to describe it as it appears in transverse sections through the cord. It then presents the appearance of the capital letter H. In each lateral half of the cord there is a semilunar or crescentic mass, shaped somewhat like a comma, the concavity of which is directed outwards and the convexity inwards. The two crescents of opposite sides are connected across the middle line by a transverse band, which receives the name of the **gray commissure** (commissura grisea). The postero-median fissure cuts through the cord until it reaches the gray commissure. The bottom of the antero-median fissure, however, is separated from it by an intervening strip of white matter, which is termed the **anterior white commissure** (commissura anterior alba). In the gray commissure may be seen the **central canal** of the cord (canalis centralis), which tunnels the entire length of the cord and is just visible to the naked eye as a minute speck. The portion of the gray commissure which lies behind the central canal is called the *posterior gray commissure* (commissura grisea posterior); whilst the portion in front receives the name of the *anterior gray commissure* (commissura grisea anterior).

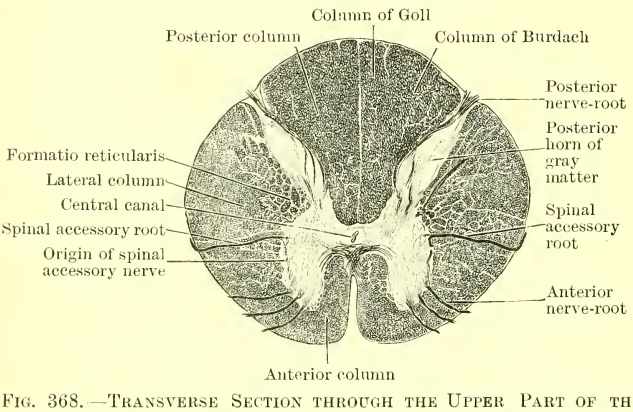


Fig. 368.—Transverse Section through the Upper Part of the Cervical Region of the Cord of an Orang. (From a specimen prepared by the Weigert-Pal method, by which the white matter is rendered dark whilst the gray matter is bleached.)

Each crescentic mass of gray matter presents certain well-defined parts. The projecting portions which extend behind and in front of the connecting transverse gray commissure are termed respectively the posterior and the anterior cornua of gray matter (columnæ griseæ). These stand out in marked contrast to each other. The **anterior cornu** (columna grisea anterior) is short, thick, and very blunt at its extremity. Further, its extremity falls considerably short of the surface of the cord and is separated from it by a tolerably thick coating of white matter. Through this the fascicles of the anterior nerve-roots, as they emerge from the gray matter of the anterior horn, pass on their way to the surface. The thickened end of the anterior cornu is called the **caput cornu**, whilst the part close to the gray commissure is termed the **cervix** or **basis cornu**. Throughout the greater part of the cord the **posterior cornu** (columna grisea posterior) is elongated and narrow, and is drawn out to a fine point, which almost reaches the bottom of the postero-lateral sulcus. This pointed extremity receives the name of the **apex cornu**; the slightly swollen part which succeeds it is the **caput cornu**; whilst the slightly constricted part adjoining the gray commissure goes under the name of the **cervix** or **basis cornu**.

The apex or tip of the posterior cornu differs considerably in appearance from the general mass of the gray matter. It is composed of a material which presents a lighter hue and has a somewhat translucent look. It is called the **substantia gelatinosa Rolandi**, and, when seen in transverse section, it exhibits a V-shaped outline and fits on the caput cornu like a cap.

A pointed and prominent triangular projection juts out from the external aspect of gray matter nearly opposite the gray commissure. This is the **lateral horn** (columna grisea lateralis), and it is best marked in the upper dorsal region (Fig.

369, B). Traced upwards it becomes absorbed in the greatly expanded anterior horn of the cervical swelling, but it reappears again in the upper part of the cord and is particularly noticeable in the second and third cervical segments; followed in a downward direction it blends with the anterior horn in the lumbar swelling and contributes to the thickening of that cornu.

The gray matter is for the most part mapped off from the surrounding white matter with a considerable degree of sharpness; but in the cervical region, on the outer aspect of the crescentic mass and in the angle between the anterior and posterior horns, fine bands of gray matter penetrate the white matter, and, joining with each other, form a network the meshes of which enclose small islands of white matter. This constitutes what is called the **formatio** or **processus reticularis**. Although best marked in the cervical region, traces of the same reticular formation may be detected in lower segments of the cord.

Characters presented by the Gray Matter in Different Regions of the Cord.—The gray matter is not present in equal quantity nor does it exhibit the same form in all regions of the cord. Indeed, each cord segment presents its own special characters in both of these respects. It is not necessary, however, in the present instance to enter into this matter with any degree of minute detail. It will be sufficient if we point out the broad distinctions which are evident in the different regions.

It may be regarded as a general law that, wherever there is an increase in the size of the nerves attached to a particular part of the cord, a corresponding increase in the amount of gray matter will be observed. It follows from this that the regions where the gray matter bulks most largely are the lumbar and the cervical swellings. The great nerve-roots which go to form the nerves of the large limb-plexuses enter and pass out from those portions of the cord. In the dorsal region there is a reduction in the quantity of gray matter in correspondence with the smaller size of the dorsal nerves.

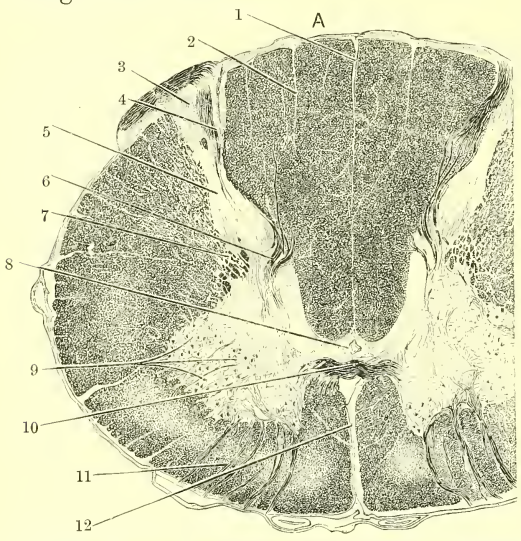
In the *dorsal region* (Fig. 369, B) both horns of gray matter are narrow, although the distinction between the anterior horn and the still more attenuated posterior horn is sufficiently manifest. In this region the lateral horn of gray matter is likewise characteristic, and the substantia gelatinosa Rolandi in transverse section is pointed and spear-shaped.

In the *upper three segments* of the *cervical region* the anterior horns of gray are not large and resemble the corresponding horns in the dorsal region. A lateral horn is also present. But in these segments (and more especially in the first and second) there is a marked attenuation of the neck of the posterior horn, and the posterior gray commissure is very broad.

In the *cervical swelling* of the cord the contrast between the two cornua is most striking; the anterior horn is of great size and presents a very broad surface towards the anterior aspect of the cord, whilst the posterior horn remains narrow. This great increase in the bulk of the anterior horn is due to a marked addition of gray matter on the outer side of the horn, and seeing that this additional matter is traversed by a greater number of fibres, it stands out, in well-prepared specimens, more or less distinctly from the part of the horn which lies to the inner side, and which may be considered to represent the entire anterior horn in the dorsal and upper cervical segments. Within this lateral addition to the anterior horn are placed those collections of cells which constitute the nuclei of origin of the motor nerves of the muscles of the upper limb. The characteristic thickening of the anterior horn of gray matter is evident, therefore, in those segments of the cord to which the nerves which enter the brachial plexus are attached, viz. the lower five cervical segments and the first dorsal segment.

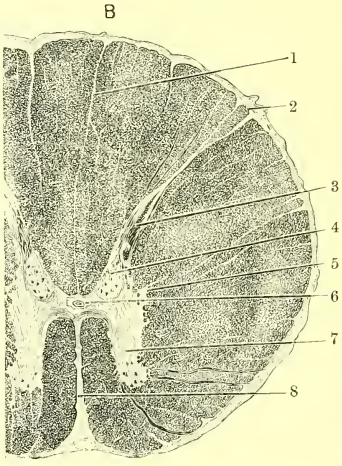
In the *lumbar swelling* the anterior horns again broaden out, and for the same reason as in the case of the corresponding horns in the cervical swelling. The nuclear masses which contain the cells from which the motor fibres which supply the muscles of the lower limbs take origin are added to the outer aspect of the horns and give them a very characteristic appearance. In this region of the cord, however, the posterior horns are also broad and capped by substantia gelatinosa Rolandi, which in transverse section presents a semilunar outline. There is

consequently no difficulty in distinguishing from an inspection of the gray matter alone between transverse sections of the cord taken from the cervical and lumbar swellings of the cord.



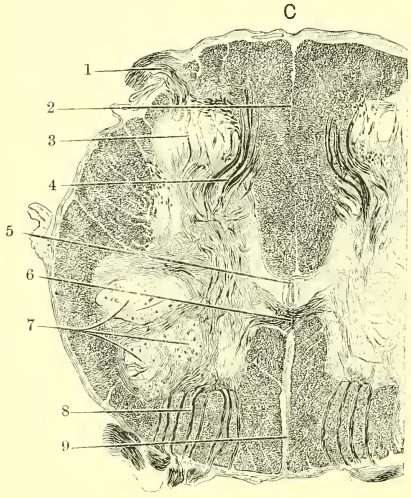
A.—Cervical region—at the level of the fifth cervical nerve. (From a specimen prepared by Dr. A. Bruce.)

1. Postero-median fissure.
2. Paramedian septum.
3. Postero-lateral groove.
4. Posterior nerve-root.
5. Substantia gelatinosa Rolandi.
6. Root-fibres entering gray matter.
7. Formatio reticularis.
8. Central canal.
9. Nuclei from which motor-fibres for muscles of upper limb arise.
10. Anterior commissure.
11. Anterior nerve-root.
12. Antero-median fissure.



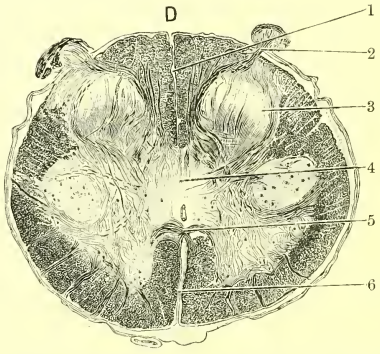
B.—Through the mid-dorsal region.

1. Postero-median fissure.
2. Postero-lateral groove.
3. Posterior cornu.
4. Posterior vesicular column of cells.
5. Lateral cornu.
6. Central canal.
7. Anterior cornu.
8. Antero-median fissure.



C.—Through the lumbar region at the level of the fourth lumbar nerve.

1. Posterior nerve-root.
2. Postero-median fissure.
3. Substantia gelatinosa Rolandi.
4. Root-fibres entering gray matter.
5. Central canal.
6. Anterior commissure.
7. Nuclei of origin from which the motor-fibres for muscles of the lower limb arise.
8. Anterior nerve-root.
9. Antero-median fissure.



D.—Through the sacral region at the level of the third sacral nerve. (From a specimen prepared by Dr. A. Bruce.)

1. Postero-median fissure.
2. Posterior nerve-root.
3. Substantia gelatinosa Rolandi.
4. Posterior gray commissure.
5. Anterior commissure.
6. Antero-median fissure.

FIG. 369.—SECTION THROUGH EACH OF THE FOUR REGIONS OF THE CORD. (From specimens prepared by the Weigert-Pal method, therefore the white matter is rendered dark in colour whilst the gray matter is bleached.)

In the lower part of the *conus medullaris* the gray matter in each lateral half of the cord assumes the form of an oval mass joined to its fellow of the opposite side by a thick gray commissure. Here almost the entire bulk of the cord consists

of gray matter, seeing that the white matter is reduced to such an extent that it forms only a thin coating on the outside.

White Matter of the Spinal Cord.—In transverse sections of the cord the three columns into which the white matter is subdivided become very apparent. The **posterior column** is wedge-shaped, and lies between the postero-median fissure and the posterior horn of gray matter. The **lateral column** occupies the concavity of the gray crescent. Behind, it is bounded by the posterior horn of gray matter and the postero-lateral sulcus, whilst in front it extends as far as the outermost fasciculi of the anterior nerve-roots as they pass out from the anterior gray horn. The **anterior column** includes the white matter between the antero-median fissure and the anterior horn of gray matter, and also the white matter which separates the broad extremity of the anterior gray cornu from the surface of the cord. This latter portion of the anterior column is traversed by the emerging fascicles of the anterior nerve-roots.

In cross-sections of the cord the partition of pia mater, which dips in at the posterior paramedian groove and divides the posterior column into the column of Goll and the column of Burdach, is very strongly marked in the cervical regions, but as it is traced downwards into the dorsal region it becomes shorter and fainter, and finally disappears altogether at the level of the eighth dorsal nerve. Below this point there is no visible demarcation of the posterior column into two parts.

The white matter is not present in equal quantity throughout the entire length of the cord. It increases steadily from below upwards, and this increase is most noticeable in the lateral and posterior columns. In the lower part of the conus medullaris the amount of gray matter is actually greater than that of the white matter: but very soon this state of affairs is changed, and in the lumbar region the proportion of gray to white matter is approximately as 1 : 2·1; in the dorsal region as 1 : 5; and in the cervical region as 1 : 5·1. When it is remembered how the gray matter expands in the lumbar and cervical regions, and how greatly it becomes reduced in the dorsal region, the significance of these figures will become more apparent.

Central Canal (canalis centralis).—As previously stated, the central canal is found in the gray commissure. It is a very minute tunnel, barely visible to the naked eye when seen in transverse section, and it traverses the entire length of the cord. Above, it passes into the medulla oblongata, and finally opens into the fourth ventricle of the brain; below, it is continued for a variable distance into the filum terminale, and in this it ends blindly. Only in the lumbar region does the central canal occupy the centre of the cord. Above this level, in the dorsal and cervical regions, it lies very much nearer the anterior than the posterior aspect of the cord; whilst below the lumbar region, as it is traced down into the conus medullaris, it inclines backwards and approaches the posterior aspect of the cord. The calibre of the canal likewise varies somewhat in different parts of the cord. It is narrowest in the dorsal region; and in the lower part of the conus medullaris it expands into a distinct fusiform dilatation (very nearly 1 mm. in transverse diameter), which is termed the **ventriculus terminalis** (Krause).

The central canal is lined by a layer of ciliated columnar cells, the deep tapering ends of which are prolonged into slender processes, which penetrate into the substance of the cord. These cells constitute the lining ependymal cells of the canal. The cilia of the epithelial cells are very early lost, and it is not uncommon to find the canal blocked up by epithelial debris.

The central canal is of interest because it represents in the adult the relatively wide lumen of the early ectodermal neural tube from which the spinal cord is developed.

Filum Terminale.—The delicate thread to which this name is applied is continuous with the lower tapered end of the conus medullaris. It is easily distinguished by its silvery and glistening appearance from the numerous long nerve-roots (cauda equina) amidst which it lies. It is about six inches long, and down to the level of the second sacral vertebra it is inclosed with the surrounding nerve-roots within the theca of dura mater. Piercing the tapered and closed end of the theca at this point, and receiving an investment from it, the filum terminale proceeds downwards in the sacral canal, and finally receives attachment to the periosteum on

the dorsal aspect of the coccyx (Fig. 364, p. 453). It is customary to speak of the filum as consisting of two parts, viz. the filum terminale internum and the filum terminale externum, or the part inside and the part outside the theca of dura mater.

The **filum terminale externum** is simply a fibrous thread, strengthened by the prolongation it receives as it pierces the dura mater. The **filum terminale internum** is largely composed of pia mater; but in its upper half it incloses the terminal part of the central canal, and around this a variable amount of the gray substance of the cord is prolonged downwards into the filum. When transverse sections are made through the upper part of the filum terminale internum some bundles of medullated nerve-fibres are observed clinging to its sides, and with these are associated some nerve-cells identical with those in the spinal ganglia. These represent rudimentary or aborted caudal nerves (Rauber).

Summary of the Chief Characters presented by the Cord in its Different Regions.

Cervical Region.	Dorsal Region.	Lumbar Region.	Sacral Region.
In transverse section, **outline of cord** transversely oval; in the middle of the cervical swelling the transverse diameter being nearly one-third longer than the antero-posterior diameter.	In transverse section, **outline of cord** more nearly circular; but still the transverse diameter is greater than the antero-posterior diameter.	In transverse section, **outline of cord** more nearly circular than in dorsal region.	In transverse section, **outline of cord**, nearly circular, but still somewhat compressed from before backwards.
Postero-median cleft very deep, extending beyond the centre of cord; **antero-median cleft** shallow.	**Postero-median cleft** very deep, extending beyond centre of cord: **antero-median cleft** shallow.	**Postero-median cleft** not nearly so deep as in regions above: **antero-median cleft**, on the other hand, much deeper.	**Postero-median** and **antero-median clefts** of equal depth.
Gray matter greatly increased in quantity in the cervical swelling: anterior horn thick and massive; posterior horn slender in comparison. Lateral horn only evident above the level of the fourth cervical nerve. Formatio reticularis strongly marked.	**Gray matter** greatly reduced in quantity. Both horns slender. Lateral horn well marked. Formatio reticularis scarcely apparent.	**Gray matter** greatly increased in the lumbar swelling. Both horns very thick and massive. Lateral horn absorbed in anterior horn. Formatio reticularis absent.	Both horns of **gray matter** very thick and massive. Lateral horn apparent. No formatio reticularis.
White matter in great quantity, and especially massed in the lateral and posterior columns.	**White matter** less in quantity than in cervical region, but bulking largely in comparison with the quantity of gray matter.	**White matter** small in quantity in relation to higher regions, and very small in amount in relation to increased quantity of gray matter.	**White matter** very small in quantity in comparison with the gray matter.
Posterior paramedian groove and septum well marked.	**Posterior paramedian groove** absent; but the corresponding septum can be traced as low down as the eighth dorsal nerve.	No **posterior paramedian groove** or septum.	No **posterior paramedian groove** and no corresponding septum.
Central canal considerably nearer the anterior surface than the posterior surface of the cord.	**Central canal** considerably nearer the anterior surface than the posterior surface of the cord.	**Central canal** in the centre of the cord.	**Central canal** in the centre of the cord.

Component Parts of the Gray Matter of the Spinal Cord.

Neuroglia enters largely into the constitution of the gray matter of the cord. It forms a bed within which the nervous elements are distributed. These nervous elements consist of (1) nerve-cells and (2) nerve-fibres—both medullated and non-medullated. The nerve-cells lie in small spaces within the neuroglia, whilst the nerve-fibres traverse fine passages the walls of which are formed of the same substance. The neuroglia is thus an all-pervading basis substance, which isolates more or less completely the nervous elements from each other, and at the same time binds them together into a consistent solid mass. In two situations the gray matter presents special characteristics which have earned for it the name of **substantia gelatinosa**, viz. the gray matter which constitutes the immediate surrounding of the central canal, and which is called the **substantia gelatinosa centralis**; and that which forms the apical part of the posterior horn of gray matter, and which receives the name of **substantia gelatinosa Rolandi**. In both situations the substantia gelatinosa stains more deeply with carmine and presents a more translucent appearance; in other respects the substantia centralis and the substantia Rolandi are very different.

The *substantia gelatinosa centralis* forms a thick ring around the central canal, which is traversed by the fine processes which proceed from the deep ends of the ependymal cells which line the canal. It is almost entirely composed of neuroglia.

In transverse sections of the cord the *substantia Rolandi*, in the cervical and dorsal regions, presents the appearance of a V-shaped mass, embracing the extremity of the caput of the posterior horn of gray matter; in the lumbar region this cap assumes a semilunar outline.

In the substantia gelatinosa Rolandi the neuroglia is present in small quantity, and small nerve-cells are developed within it in considerable numbers.

Nerve-Cells.—The nerve-cells are scattered plentifully throughout the gray matter, but perhaps not in such great numbers as might be expected when we note the enormous number of nerve-fibres with which they stand in relation. They are all, without exception, multipolar, and send off from their various aspects several branching protoplasmic processes or dendrites, and one axon, which becomes the axis-cylinder of a nerve-fibre. In size they vary considerably, and it is generally admitted that the bulk of a nerve-cell has a more or less definite relation to the length of the axis-cylinder which proceeds from it.

When the nerve-cells are studied in a series of transverse sections of the cord, it will be noticed that a large proportion of them are grouped in clusters in certain districts of the gray matter; and as these groups are seen in very much the same position in successive sections, it is clear that these cells are arranged in longitudinal columns of greater or less length. Thus we recognise (1) a ventral group or column of cells in the anterior horn of gray matter; (2) an intermedio-lateral group or column in the lateral horn of gray matter, where this exists; and (3) a posterior vesicular column of cells (Clarke's column), forming a most conspicuous group in the mesial part of the cervix of the posterior horn in the dorsal region of the cord.

Other cells besides those forming these columns are scattered somewhat irregularly throughout the gray matter of the posterior horn and the part of the gray crescent which lies between the two horns; and although these also in some measure may be classified into groups, the arrangement thus effected is not of so definite a character as to justify us in dwelling upon it in the present instance.

Ventral Cell-Column and the Origin of the Fibres of the Anterior Nerve-Roots.—The ventral cell-group occupies the anterior horn of gray matter, and in it are found the largest and most conspicuous cells in the spinal cord. It extends from one end of the cord to the other. These ventral nerve-cells have numerous wide-spreading dendritic processes, and it is to be noticed that certain of these dendrites do not confine their ramifications to the gray matter. Thus, some of the cells along the mesial border of the anterior horn of gray matter send dendrites across the mesial plane in the anterior commissure to end in the anterior gray horn of the opposite side; whilst others, lying along the lateral or outer margin of

the anterior horn of gray matter, send dendrites in amongst the nerve-fibres of the adjoining white matter.

The axons or axis-cylinder processes of a large proportion of the ventral cells converge together; and, becoming medullated, form bundles which pass out from the gray matter, and through the white matter which separates the thick end of the anterior horn from the surface of the cord, to finally emerge as the fascicles of the anterior nerve-roots. These cells, then, are the sources from which the nerve-

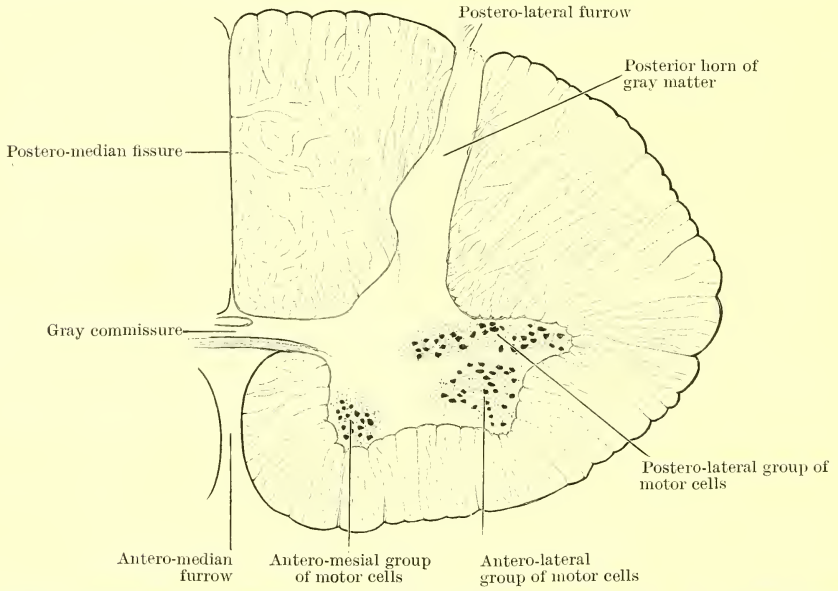


Fig. 370.—Section through the Fifth Cervical Segment of the Cord. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

fibres of the anterior nerve-roots proceed, and in consequence they are frequently spoken of as the "motor cells" of the cord. Whilst this is the arrangement of the axons of the great majority of the motor cells, it should be noted that a few cross the mesial plane in the anterior white commissure and emerge in the fascicles of origin of the opposite anterior nerve-root.

The ventral cells are not scattered uniformly throughout the anterior horn of gray matter. They are aggregated more closely together in certain parts of the anterior horn, and thus form sub-groups or columns more or less perfectly marked off from each other.

Thus one sub-group or column of ventral cells occupies the inner or mesial part of the anterior horn of gray matter throughout almost its whole length. In only two segments of the cord is it absent, viz. the fifth lumbar and the first sacral; at this level in the cord alone is its continuity broken (Bruce). It is termed the *ventro-mesial column* or *group* of ventral cells. Behind this cell-column there is another which is classed with it to which the name of *dorso-mesial column* or *group* is given, but this column of cells is not continuous throughout the entire length of the cord. It is present in the dorsal region of the cord where the motor nuclei for the muscles of the limbs are absent, and it is also seen in two or three of the segments of the cervical region and in the first lumbar segment (Bruce); elsewhere it is not represented.

In the cervical and lumbar swellings of the cord, where the marked lateral outgrowth is added to the outer side of the anterior horn of gray matter, certain groups of large multipolar cells are visible. These are the nuclei of origin of the motor-fibres which supply the muscles of the limbs, and consequently they are not represented in the upper three cervical segments of the cord; nor in any of the dorsal segments, with the exception of the first dorsal segment; nor in the two lowest sacral segments.

These *lateral cells* are arranged in several columns, which extend for varying distances in the superadded lateral parts of the anterior horn of gray matter. The two main columns are a *ventro-lateral* and a *dorso-lateral column*; in certain segments there is likewise a *post-dorso-lateral column*, and in a number of segments in the lumbar and sacral regions a *central column* of cells (Bruce).

There cannot be a doubt that the grouping of the motor cells in the anterior horn of gray matter of the cord stands in relation to the muscle groups to which their axis-cylinder processes are distributed; but from what has been said it will be apparent that sharply defined cell-clusters associated with particular muscles do not exist. Still, much can be learned regarding the localisation of the motor nuclei in the anterior horn of gray matter of the cord from the study of the changes which occur in the cell-columns after atrophies of isolated muscles or groups of muscles, and after complete or partial amputations of limbs. It has been pointed out that the long muscles of the trunk (as, for example, the different parts of the erector spinae muscle) receive nerve-fibres from all the segments of the cord. Now, we have noted that there is only one cell-column, the ventro-mesial column, which pursues an almost uninterrupted course throughout the entire length of the cord. It may be assumed, therefore, that the nerve-fibres which go to these long trunk-muscles take origin in these mesial cells.

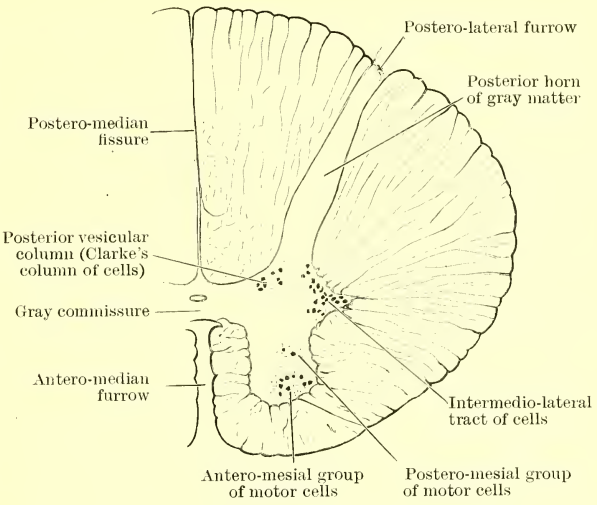


FIG. 371.—SECTION THROUGH THE EIGHTH DORSAL SEGMENT OF THE SPINAL CORD. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

Edinger states that in the anterior horn of gray matter the nuclei of origin of the nerves which supply the proximal muscles are medially placed; that those for the distal muscles are in general situated laterally. If this be the case, the cells connected with the shoulder muscles would lie nearer the middle of the anterior horn of gray matter than those which are connected with the hand-muscles. In cases where the forearm and hand, or the leg and the foot, are amputated, it would appear that it is the postero-lateral column of cells that shows changes in consequence of its separation from the muscles to which its fibres are distributed.[1]

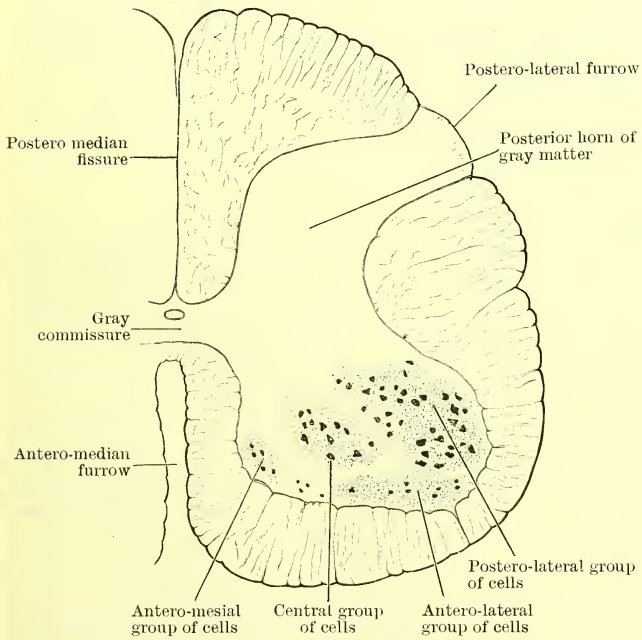


FIG. 372.—SECTION THROUGH THE THIRD LUMBAR SEGMENT OF THE SPINAL CORD TO SHOW THE GROUPING OF THE MOTOR CELLS. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

Intermedio-lateral Cell-column.—The intermedio-lateral cells form a long slender column which extends throughout the entire dorsal region of the cord in the lateral horn of gray matter. It is also prolonged downwards into the first and second lumbar segments, where it disappears. In

[1] Those who seek further information regarding the grouping of the ventral cells of the cord, may with advantage study Dr. Alexander Bruce's *Atlas of the Spinal Cord*.

transverse sections through the cord this cell-group presents a very characteristic appearance, because the cells which compose it are small and are closely packed together. Although these cells, as a continuous column, are restricted to the region indicated, it should be noted that the same group of cells reappears above in certain of the cervical segments and also in the third and fourth sacral segments. The function and connexions of these cells are unknown. It has been suggested that they give origin to vaso-motor, pilo-motor, and sweat-gland nerves, and have a very close connexion with the sympathetic nervous system.

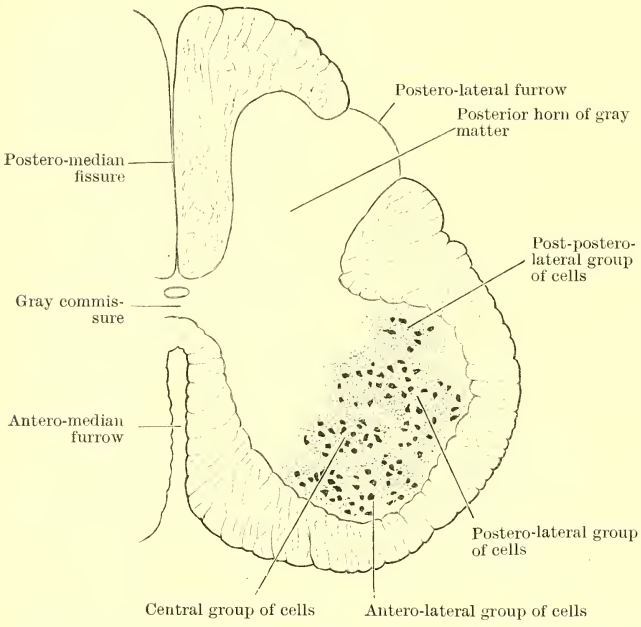


FIG. 373.—SECTION THROUGH THE FIRST SACRAL SEGMENT OF THE SPINAL CORD TO SHOW THE GROUPING OF THE MOTOR NERVE-CELLS. (To a large extent founded on Plates in Dr. Bruce's *Atlas*.)

In a recent research by Bruce the following important points in regard to the intermedio-lateral cell-column have been determined.

It is not quite continuous. In the eighth cervical, first dorsal, and also in a part of the second dorsal segment, as well as in the first and second lumbar segments, the cells are in separate clusters. Throughout the rest of the dorsal region it forms a moniliform chain of cells, situated partly in the lateral horn and partly in the gray matter behind it. Some outlying cells are situated in the white matter in the neighbourhood of the lateral horn.

The limits of the tract are from lower two-thirds of eighth cervical to the lower end of the second lumbar or perhaps the upper end of the third lumbar segment. It is found also in the first, second, and third cervical, and in the third and fourth sacral segments. It reaches its maximum size in the third and fourth dorsal segments.

Posterior Vesicular Column—Clarke's Column.—This occupies the posterior horn of gray matter and is the most conspicuous of all the cell-groups in the cord. It does not, however, extend along the whole length of the cord; indeed it is almost entirely confined to the dorsal region, and in consequence it is sometimes referred to as the "dorsal nucleus." Above, it begins opposite the seventh or eighth cervical nerve, whilst below, it may be traced to the level of the second lumbar nerve, where it disappears. In transverse section of the cord it presents an oval outline, and is seen in the inner part of the cervix of the posterior horn of gray matter immediately behind the gray commissure (Fig. 369 B, p. 458). On the outer side it is circumscribed by numerous curved fibres from the entering posterior nerve-root, and in the lower dorsal region of the cord (opposite the eleventh and twelfth dorsal nerves) it becomes so marked that it forms a bulging on the inner aspect of the posterior gray horn.

The cells of Clarke's column are large, and possess several dendritic processes. The axons enter the lateral column of white matter and there form a strand of fibres, which will later on be described under the name of the **direct cerebellar tract.**

In addition to the topographical subdivision of the nerve-cells of the cord indicated above, it is now usual to classify them according to the nature of the axons which proceed from them. Thus we have (1) the cells of Golgi or cells with short axons, and (2) cells with long axons.

The **cells of Golgi** possess axons which do not emerge from the gray matter, but bring neighbouring cells into touch with each other. The **cells with long axons** are of two kinds, viz. radicular cells and strand-cells.

The **radicular cells** are those from which the axon emerges from the cord in the shape of an efferent nerve-fibre. Thus the "motor cells" which supply the axis-cylinder processes of the

anterior nerve-roots belong to this class. The **strand-cells** are those which contribute their axons to the formation of those fibres which form certain of the strands or tracts which are found in the white matter of the cord.

Nerve-fibres in the Gray Matter of the Cord.—Nerve-fibres both of the medullated and non-medullated variety pervade every part of the gray matter. They are of three kinds, viz. (1) collaterals, (2) terminations of nerve-fibres, (3) axons given off by the cells. Many of the nerve-fibres which compose the columns of white matter of the cord give off numerous fine collateral branches, which pass into the gray matter from all sides and finally end in relation with the nerve-cells. The majority of the nerve-fibres themselves, which thus give off collaterals, finally enter the gray matter, and end similarly. As already noted, the axons of the cells of Golgi remain within the gray matter, but the others emerge either for the purpose of entering a peripheral nerve or for the purpose of entering a strand of fibres in the white matter of the cord.

The nerve-fibres thus derived are interwoven together in the gray matter of the cord in a dense inextricable interlacement.

Component Parts of the White Matter of the Cord.

The white matter of the cord is composed of medullated nerve-fibres embedded in neuroglia. The fibres, for the most part, pursue a longitudinal course; and from the deep surface of the pia mater which surrounds the cord fibrous septa or partitions are carried in along vertical planes between the fibres, so as to form an irregular and very imperfect fibrous framework of support. The neuroglia is disposed in a layer of varying thickness around the cord, subjacent to the pia mater, and is carried into the cord so as to give a coating to both sides of the various pial septa. The neuroglia also is disposed around the various nerve-fibres, so that each of these may be said to lie in a canal or tunnel of this substance. The nerve-fibres are all medullated, but they are not provided with primitive sheaths. It is the medullary substance of the nerve-fibres which gives to the white matter its opaque, milky-white appearance. When a thin transverse section of the cord is stained in carmine and examined under the microscope the white matter presents the appearance of a series of closely-applied circles, each with a dot in the centre. The dot is the transversely divided axis-cylinder of a nerve-fibre, and the dark ring which forms the circumference of the circle represents the wall of the neuroglial canal which is occupied by the fibre. The medullary substance is very faintly seen. It presents a filmy or cloudy appearance between the axis-cylinder and the neuroglial ring.

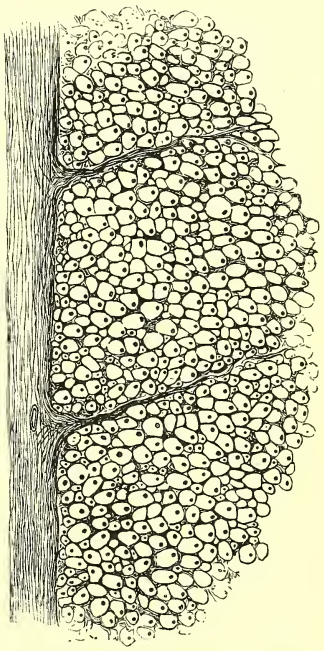


Fig. 374.—Transverse Section through the White Matter of the Cord, as seen through the microscope.

Arrangement of the Nerve-fibres of the White Matter in Strands or Tracts.—When the white matter of a healthy adult cord is examined the fibres which compose it are seen to vary considerably in point of size; and although there are special places where large fibres—or it may be small fibres—are present in greater numbers than elsewhere, yet as a rule both great and small fibres are mixed up together. Absolutely no evidence can be obtained in such a cord, by any means at our disposal, of the fact that the longitudinally arranged fibres are grouped together in more or less definite tracts or strands, the fibres of which run a definite course and present definite connexions. Yet we know this to be the case, and the existence of these separate tracts has been proved both by physiological and by embryological investigation.

The **physiological evidence** depends on the fact that when a nerve-fibre is severed the part which is detached from the nerve-cell from which it is an offshoot degenerates, whilst the part which remains connected with the nerve-cell undergoes little or no change. This is called the law of "Wallerian" degeneration. Thus, if in a living animal one-half of the cord be cut across, and after a few weeks the animal be killed and the cord examined, it will be seen that there are degenerated tracts of fibres in the white matter, both above and below the plane of division; but, still further, it will also be manifest that the tracts which are degenerated above the plane of division are not the same as those which are degenerated in the part of the cord which lies below this level. The interpretation of this is obvious. The nerve-tracts which have degenerated above the plane of section are the offshoots of nerve-cells which lie in lower segments of the cord or in spinal ganglia below the plane of section. Severed from these nerve-cells, they undergo what is called ascending degeneration. The nerve-tracts, on the other hand, which have degenerated in the portion of the cord below the plane of division are the axons of cells which lie at a higher level than the plane of section, either in higher segments of the cord or in the brain itself. Cut off from the nerve-cells from which they proceed, they present an example of descending degeneration.

The **embryological evidence** we owe to Flechsig, and it is no less satisfactory. It depends upon the fact that nerve-fibres in the earliest stages of their development consist of naked axis-cylinders, and are not provided with medullary sheaths. Further, the nerve-fibres of different strands assume the medullary sheaths at different periods. By examining the fœtal cord at different stages of its development, it is a comparatively easy matter to locate the different tracts of fibres by evidence of this kind. Speaking broadly, the tracts which myelinate first are those which bring the cord into relation with the peripheral parts (skin, muscles, etc.); then those fibres which bind the various segments of the cord together; next, those which connect the cord with the cerebellum; and, lastly, the tracts which connect the cord with the cerebrum. The nervous apparatus for the performance of automatic movements is fully provided, therefore, before this is put under the control and direction of the higher centres. It by no means follows that in all the higher animals corresponding strands myelinate at relatively corresponding periods. Take the case of a young animal which from the time of its birth is able to move about and perform voluntary movements of various kinds in a more or less perfect manner, and compare it with the helpless new-born human infant which is only capable of exhibiting automatic movements. In the former the pyramidal tracts, or motor tracts, which descend from the cerebrum into the cord, and which are the paths along which the mandates of the will travel, myelinate at an early period; whilst in the human infant the corresponding fibres do not obtain their medullary sheaths until after birth. The study of the dates, therefore, at which the various strands of nerve-fibres myelinate not only gives the anatomist a means of locating their position in the white matter of the cord, but it also affords the physiologist most important information regarding their functions, and also the periods at which these functions are called into play.

It is a matter of interest to note that influences which either accelerate or retard the periods at which nerve fibres are brought into functional activity have also an effect in determining the dates at which these fibres assume their sheaths of myelin. Thus, when a child is prematurely born the whole process of myelinisation is, as it were, hurried up; and further, when in new born animals light is freely admitted to one eye whilst it is carefully excluded from the other, the fibres of the optic nerve of the former myelinate more rapidly than those of the opposite nerve.

Posterior Column of the Cord and the Posterior Roots of the Spinal Nerves.—In the cervical and upper dorsal regions of the cord the posterior column is divided by the posterior paramedian septum into the **tract of Burdach**, which lies externally and next the posterior horn of gray matter, and the **tract of Goll**, which lies internally and next the postero-median septum. The tract of Burdach is composed of nerve-fibres, which are for the most part larger than those entering into the formation of Goll's tract, and both tracts have a most intimate relation to the posterior nerve-roots; indeed, they are both almost entirely composed of fibres which enter the cord by these roots and then pursue a longitudinal course.

The nerve-fibres which form the posterior nerve-roots, on entering the cord along the postero-lateral groove, divide within the tract of Burdach into ascending and descending branches. These branches diverge abruptly from each other; and the former take an upward course, whilst the latter proceed downwards. The **descending fibres** are as a rule short, and soon end in the gray matter of the cord. These descending fibres occupy an area in the posterior column near to the place of entrance of the nerve-root. This area, when the spinal cord is divided, undergoes descending degeneration and then presents a comma-shaped outline. The fibres in question are included under the name of the **comma tract of Schultze.**

The **ascending fibres** vary greatly in length, and at varying distances from the point where the parent fibres enter the cord they end in the gray matter. A small contribution of ascending fibres, however, from each posterior nerve-root, extends upwards to the upper end of the cord, to end in the medulla oblongata.

As each posterior nerve-root enters, its fibres range themselves in the outer part of

the tract of Burdach close up against the posterior horn of gray matter. The nerve-

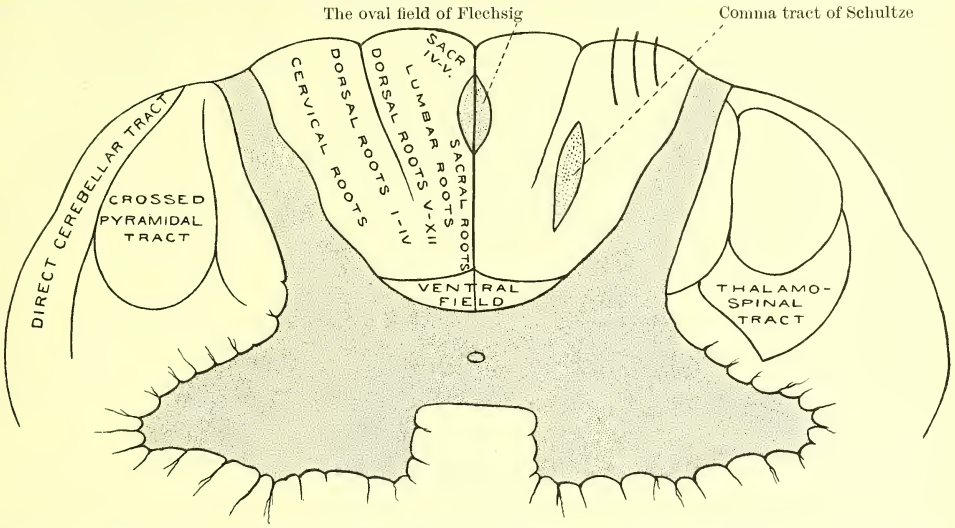


FIG. 375. — DIAGRAM TO SHOW THE ARRANGEMENT OF THE FIBRES OF THE POSTERIOR NERVE-ROOTS IN THE POSTERIOR COLUMNS OF THE CORD. The oval field of Flechsig is present in the lumbar region and is composed of fibres which degenerate in a downward direction, and which are not derived from the posterior nerve-roots. In all probability they are commissural fibres (from Edinger, modified).

fibres of the nerve-root next above take the same position, and consequently those which entered from the nerve immediately below are displaced inwards, and come to lie in the tract of Burdach nearer to the mesial plane. This process goes on as each nerve-root enters, and the result is that the fibres of the lower nerves are gradually pushed nearer and nearer to the postero-median septum in a successive series of lamellar tracts. Of course the greater proportion of the fibres, which are thus carried upwards from the posterior nerve-roots, sooner or later leave the posterior column and enter the gray matter, to end there in relation to some of its cells; but, as we have said, every posterior nerve-root sends a few fibres up the whole length of that portion of the cord which lies above, and thus the posterior column gradually increases in bulk as it is traced upwards, and in the upper reaches of the cord a tract of Goll becomes evident. This tract of Goll is composed of the long ascending fibres of the posterior nerve-roots, which have entered the lower segments of the cord. To put the matter differently, the fibres of the sacral roots are displaced inwards by the entering lumbar fibres, while the fibres of the lumbar roots are in their turn pushed inwards by the entering dorsal fibres, and, lastly, the fibres of the cervical roots displace the dorsal fibres. The difference between the tract of Goll and the tract of Burdach simply consists in this, that the former is composed of the fibres of posterior nerve-roots which have entered the cord at a lower level than those which enter into the formation of the column of Burdach. The fibres of Goll's tract, taking them as a whole, must therefore necessarily run a very much longer course.

Our knowledge of the constitution of the posterior columns of the cord is largely derived from studying the course of degeneration in monkeys, in which the cord has been cut across—either partially or completely. It would appear, from the examination of the human cord which has been injured or compressed, that the lamination of the fibres entering from the series of posterior nerve-roots is not nearly so complete as in the case of the monkey.

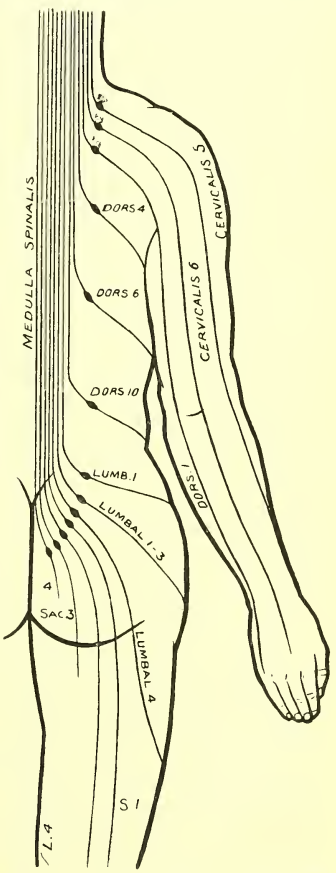


FIG. 376.—DIAGRAM TO SHOW THE MANNER IN WHICH THE FIBRES OF THE POSTERIOR NERVE-ROOTS ENTER AND ASCEND IN THE POSTERIOR COLUMN OF THE CORD (from Edinger).

Numerous collateral fibrils stream into the gray matter of the posterior horn both from the ascending and descending branches of the entering fibres of the posterior nerve-roots. These are classified into long and short collaterals. The **long collaterals** extend forward into the anterior horn of gray matter and end in relation to the ventral nerve-cells. The **short collaterals** end in relation to the nerve-cells in the substantia Rolandi, and other nerve-cells of the posterior horn of gray matter.

The majority of the fibres of the posterior nerve-root enter the cord on the inner side of the apex of the posterior horn of gray matter. The manner in which these are related to the columns of Burdach and Goll has been noticed ; but a certain number of those fibres which lie most externally take a curved course forwards on the inner side of the posterior horn of gray matter and then pass into it. In the dorsal region these curved fibres end in connexion with the cells of Clarke's column (Fig. 369, p. 458).

Tract of Lissauer.—This is a small tract of nerve-fibres of minute calibre which assume their medullary sheaths at a comparatively late period. It is placed at the surface of the cord close to the postero-lateral furrow. It is formed by some of the outer fibres of the posterior nerve-roots, which do not enter the tract of Burdach, and which pass upwards in the cord close to the substantia gelatinosa Rolandi, in which they ultimately end.

It must now be evident that the fibres which enter the cord through each posterior nerve-root have three main modes of distribution : (1) the majority take part in the formation of the columns of Burdach and Goll ; (2) a few lie close to the posterior horn of gray matter and describe a series of graceful curves as they pass forwards prior to turning outwards into the gray matter, to end, in the dorsal region, in Clarke's vesicular column ; (3) a third series form Lissauer's tract and end in connexion with the cells of the substantia gelatinosa Rolandi and other cells in the posterior and anterior horns of gray matter.

The fibres derived from the posterior nerve-roots which ascend in the posterior columns of the cord to the medulla oblongata of the brain constitute a direct sensory tract ; other fibres are described which give rise to a crossed sensory tract termed the **spino-thalamic tract.** These latter fibres arise as the axons of certain of the cells in the posterior horn in connexion with which fibres from the posterior nerve-roots have ended, and crossing to the opposite side of the cord through the anterior commissure they ascend in the anterolateral column to the brain, where they ultimately reach the optic thalamus. As the spino-thalamic tract ascends in the cord its fibres are not gathered into a compact strand, but are more or less loosely scattered in the lateral column.

Association Fibres in the Posterior Column.—But the whole of the fibres of the posterior column are not derived from the posterior nerve-roots. A few fibres exist in this column which have a different origin. They are derived from certain of the cells of the gray matter of the cord, and entering the posterior column divide into ascending and descending branches which pass upwards and downwards in the column for a varying distance before they finally turn in to end in the gray matter at a higher and a lower level. These fibres, therefore, constitute links of connexion between different cord segments, and thus they are termed **association** or **longitudinal commissural fibres.** Our information regarding these fibres at present is somewhat defective ; but it is believed that the deepest part of the column, *i.e.* the part next the posterior gray commissure and termed the **ventral field,** and also the **descending septo-marginal tract** of Bruce, placed in apposition with the postero-median septum and in the adjoining part of the surface, belong mainly to this category.

Lateral Column of the Cord.—In the lateral column of the cord the well-established tracts are :—

1. The direct cerebellar tract.
2. The tract of Gowers.
3. The crossed pyramidal tract.

The remainder of the column goes under the name of the **lateral basis-bundle.**

The **direct cerebellar tract** (fasciculus cerebello-spinalis) is a band-like strand which lies in relation to the surface of the cord immediately in front of the postero-lateral groove. It is an ascending tract, and is composed for the most part of coarse, large nerve-fibres, which are derived from the nerve-cells of the posterior vesicular column (Clarke's column) in the posterior horn of gray matter. It is, therefore, not found throughout the whole length of the cord. It first appears in the lower part of the dorsal region ; and as it ascends it gradually increases in size as it is joined by the axons of the cells of Clarke's column, which lie at higher levels. It finally enters the medulla oblongata, and through this proceeds to the cerebellum, in which it ends.

It must not be forgotten that each posterior nerve-root in the dorsal region of the cord gives a contribution of fibres to the posterior vesicular column of cells from which the fibres of the direct cerebellar tract arise (see p. 468). In this way a connexion is established between the posterior roots of the dorsal nerves and the cortex of the cerebellum. It is believed that the direct cerebellar tract is an important factor in bringing about a proper co-ordination of muscular movements.

Gowers's tract (fasciculus antero-lateralis superficialis) lies in front of the direct cerebellar tract, and, like it, next the surface of the lateral column. It is also an ascending tract, and it likewise (in part at least) ultimately reaches the cerebellum, although after leaving the cord it takes a different route to gain its destination. In transverse sections of the cord it presents a comma-shaped appearance, the thick part abutting against the direct cerebellar tract, and the narrower portion tapering forwards into the region of the emerging anterior nerve-roots. The tract of Gowers begins at a lower level in the cord than the direct cerebellar tract and it increases in volume as it is traced upwards. The fibres of this tract have probably their origin in the cells of the posterior horn of gray matter, but on this point there is at present no precise information.

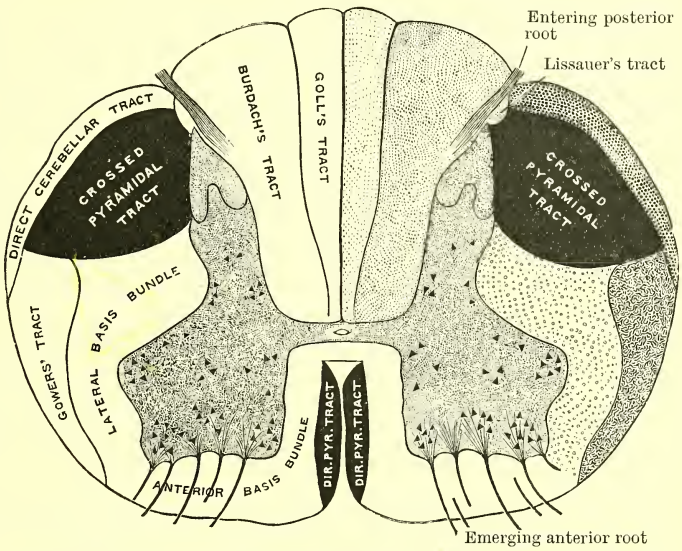


Fig. 377.—Diagrammatic Representation of a Transverse Section through the Spinal Cord.

The nerve tracts in the white matter and the clusters of nerve-cells in the gray matter are shown.

The **crossed pyramidal tract** (fasciculus cerebro-spinalis lateralis) is a large well-defined descending tract, which lies immediately in front of the posterior horn of gray matter and subjacent to the direct cerebellar tract, which shuts it out from the surface of the cord. Below the point where the direct cerebellar tract begins the crossed pyramidal tract becomes superficial, and in this position it can be traced as low as the fourth sacral nerve, at which level it ceases to exist as a distinct strand. The crossed pyramidal tract is composed of an admixture of both large and small fibres. These arise in the brain from the large pyramidal cells of the motor or Rolandic area of the cerebral cortex, and pass downwards through various subdivisions of the brain to gain the spinal cord. As they enter the cord they cross the mesial plane from one side to the other, and it thus happens that the crossed pyramidal tract in the right lateral column of the cord has its origin in the cortex of the left cerebral hemisphere, and *vice versa*. As the tract descends in the cord it gradually diminishes in size; and this is due to the fact that, as it traverses each spinal segment, numerous fibres leave it to enter the anterior horn of gray matter, and end in connexion with the ventral motor cells from which the fibres of the anterior nerve-roots arise. The entire strand is ultimately exhausted in this way. Numerous collateral fibrils spring from the pyramidal fibres, and, entering the gray matter, end in a similar manner, and in this way a single pyramidal fibre may be connected with several spinal segments before it finally ends. The crossed pyramidal tract must be regarded as a great motor strand which brings the spinal motor apparatus under the control of the will.

Schäfer believes that many of the pyramidal fibres end in connexion with the cells of Clarke's column.

In the rat, mouse, guinea-pig, squirrel, sheep, kangaroo, etc., the pyramidal tract lies in the posterior column of the cord.

The **lateral basis-bundle** (fasciculus lateralis proprius) represents the remainder of the lateral column. Our information regarding it is still imperfect; but it would appear that its fibres are largely derived from the cells situated in all parts of the gray matter, and also from the nerve-cells of the opposite side of the cord. After a course of very varying length in the basis-bundle, these fibres turn inwards and re-enter the gray matter. Such fibres may thus be regarded as **inter-segmental association fibres** binding two or more segments of the cord together. It may be mentioned that the association fibres which link together segments of the cord which are near to each other lie close to the gray matter, whilst those which connect the more distant segments are situated further out in the lateral basis-bundle.

Anterior Column of the Cord.—One well-defined tract is situated in the anterior column. This is termed the direct pyramidal tract. The remainder of the column receives the name of the anterior basis-bundle.

The **direct pyramidal tract** (fasciculus cerebro-spinalis anterior) is usually a nerve-strand of small size which lies next the antero-median fissure. As a rule, it cannot be traced lower than the middle of the dorsal region of the cord. It is a descending tract and must be associated with the crossed pyramidal tract of the opposite side, seeing that both of these strands arise from the motor area of the cortex of the same cerebral hemisphere. From this, it must be clear that the direct pyramidal tract does not cross the mesial plane as it enters the cord, but descends on the side of the cord corresponding to the cerebral hemisphere in which it arises. All the same its fibres do not end in the same side of the cord, but at every step along the path of the strand they make use of the anterior commissure and cross to the opposite side of the cord, to terminate in relation to the opposite ventral motor cells in the same manner as the crossed pyramidal fibres.

From this crossing of the pyramidal tracts, it results that the destruction of the fibres which compose them as they descend in one side of the brain must result in paralysis of the muscles supplied by the efferent nerves of the opposite side of the cord.

In cases of old brain lesion it is sometimes possible to detect some degenerated fibres in the crossed pyramidal tract of the sound side of the spinal cord, and from this it is supposed that this tract contains a few uncrossed fibres. If this be the case, each side of the cord stands in connexion with the motor area of both cerebral hemispheres.

It is well to note that the fibres of both pyramidal tracts are not medullated until the time of birth. They are the latest of all the cord-tracts to myelinate.

The **anterior basis-bundle** (fasciculus anterior proprius), like the lateral basis-bundle, is composed largely of fibres which arise from the cells of the gray matter of the cord, and act the part of **intersegmental association fibres.**

Summary of the Constitution of the White Matter of the Cord.—The white columns of the cord are formed of two kinds of nerve-fibres :—

1. Those which enter the cord from without.

2. Those which take their origin from the cells within the gray matter of the cord itself.

Under the first category we include (*a*) the greater part of the fibres of the posterior column (columns of Burdach and Goll), which arise from the cells of the spinal ganglia, and which enter the cord as the posterior nerve-roots; and (*b*) the crossed and direct pyramidal tracts which come from the motor cells of the cerebral cortex.

The fibres which arise within the gray matter of the cord may be classified thus: (*a*) Fibres which pass out from the cord as efferent nerves (anterior nerve-roots); (*b*) fibres which form long tracts and pass up the cord to enter the brain (direct cerebellar tract and the tract of Gowers); (*c*) fibres which form short tracts, linking together different segments of the cord (intersegmental association fibres in each of the three columns of the cord).

Anterior White Commissure.—The anterior commissure is composed of medullated nerve-fibres passing from one side of the cord to the other and entering the anterior horn of gray matter, and also the anterior column of white matter. It is to be regarded more as a decussation than as a commissure, and its width, which

varies somewhat in different regions, fluctuates in correspondence with the diameter of the cord.

Amongst the fibres which cross in the anterior commissure may be mentioned: (1) The fibres of the direct pyramidal tract; (2) collaterals from both the ventral and lateral columns; (3) axons of many of the cells of the gray matter; (4) the dendritic processes of some of the mesial ventral cells.

Posterior Gray Commissure.—Although this is composed of gray matter with a large admixture of neuroglia, numerous transverse nerve-fibres pass through it, so as to bind the cells of one side of the cord to those of the other.

Development of the Spinal Cord.

In the chapter upon General Embryology it has been pointed out (p. 21) that the brain and cord first take shape in the form of a tube of ectoderm, which receives the name of the **neural tube**. Three expansions, placed one behind the other at the cephalic end of the tube, represent the early brain; whilst behind these primitive cerebral vesicles comes the elongated narrower part of the tube, which at this stage represents the spinal cord. By a developmental process, which we now have to study, the walls of this portion of the neural canal give rise to the various elements which build up the substance of the cord, whilst a portion, if not the whole, of the primitive cavity is preserved as the central canal of the cord. The account which is here given of the development of the cord is taken almost entirely from the writings of Professor His.

When first formed, the neural tube is compressed from side to side and presents an oval outline in transverse section (Fig. 16, p. 21). The two lateral walls are very thick, whilst the narrow dorsal and ventral portions of the wall are thin, and are termed the **mid-dorsal** and **mid-ventral laminæ** (Fig. 378). The cavity of the tube in transverse section appears as a narrow slit. At this stage the wall of the neural tube is formed of a series of elongated neuro-epithelial columnar cells, closely applied to each other and extending throughout the whole thickness of the wall. The inner ends of these long columnar cells unite to form a delicate membrane termed the **internal limiting membrane**, which lines the lumen of the tube, whilst their outer ends present a similar relation to an **external limiting membrane**, which invests the outer surface of the tube. The name of **spongioblasts** is given to these cells, and they soon develop in such a manner as to form the sustentacular framework of the growing cord. Between their inner parts, immediately subjacent to the internal limiting membrane, a series of clefts or open spaces are formed, in which appear large numbers of round cells called **germinal cells.** The precise origin of these germinal cells is not at present satisfactorily established; but they rapidly increase in number, and in the human embryo of four weeks they are seen to form an almost continuous layer beneath the internal limiting membrane. It is well to note, however, that in the thin mid-dorsal and mid-ventral laminæ no germinal cells are formed. Here the wall remains purely spongioblastic. The peripheral portions of the spongioblasts likewise undergo a marked transformation. They give off branches or processes, and by the interlacement of these a sponge-like network with irregular meshes is formed in the outer portion of the wall of the neural tube. The

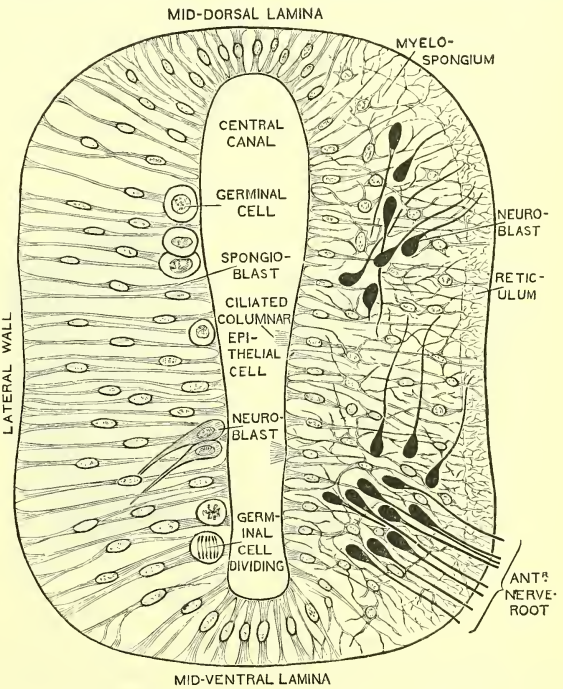


Fig. 378.—Schema of a Transverse Section through the Early Neural Tube (Young).

The left side of the section shows an earlier stage than the right side.

entire sustentacular framework into which the spongioblasts are developed is termed the **myelosponge.**

The numerous germinal cells which are placed in the clefts between the inner columnar portion of the myelosponge are the progenitors of the nerve-cells. Many of them show karyokinetic stages, and by their division they give rise to the **neuroblasts** or young nerve-cells. A neuroblast presents a very characteristic pear-shaped appearance. From the body of the cell a tapering process grows out, and this represents the early axis-cylinder process or axon of the cell. But the crowds of neuroblasts which are thus formed do not remain in their early primitive position beneath the internal limiting membrane. They migrate outwards, and in the course of time they come to lie in the part of the myelosponge immediately adjoining the reticular meshwork, which is formed by the outer parts of the spongioblasts. Here their further outward migration is arrested. The reticular meshwork would almost appear to act as a sieve or a filter, which prevents their progress towards the periphery of the wall of the tube. It offers no impediment to the actively growing axons of the neuroblasts, however, which freely enter it and thread their way through it. At this stage the thick lateral wall of the neural tube presents three layers, viz. :—

1. An inner layer, formed by the columnar part of the myelosponge forsaken by the neuroblasts. This is termed the **ependymal layer**, and it ultimately resolves itself into the layer of columnar ciliated epithelial cells which lines the central canal of the cord.

2. An intermediate layer, in which the neuroblasts are present, and which is afterwards converted into the gray matter of the cord. This is called the **mantle layer.**

3. An outer layer, formed of the sponge-like meshwork of the outer parts of the original spongioblasts. Into this the axons of many of the neuroblasts are seen threading their way. This layer is ultimately transformed into the white matter of the cord, and at this stage it may be termed the **peripheral reticular layer.**

Alar and Basal Laminæ of the Lateral Wall of the Neural Tube.—From what has been said, it must be evident that the changes detailed above are confined to the thick lateral walls of the neural tube. In these alone do neuroblastic cells arise, whilst the thin mid-dorsal and mid-ventral laminæ remain spongioblastic throughout. But whilst these changes are going on, the thick lateral wall begins to bulge outwards in an angular fashion, so as to widen the central cavity of the tube and become itself, along the line where the cavity is widest, demarcated into two portions—a narrow dorsal strip termed the **alar lamina**, and a broader ventral strip called the **basal lamina.** The cavity

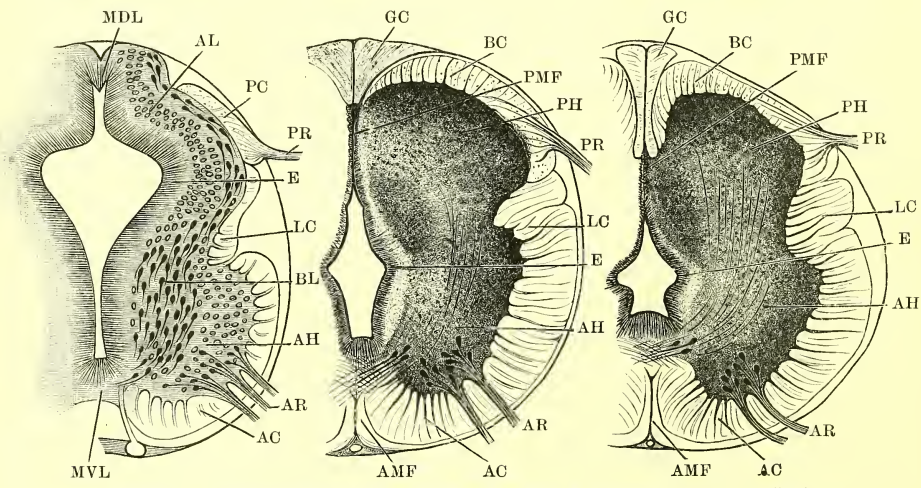


FIG. 379.—THREE STAGES IN THE DEVELOPMENT OF THE SPINAL CORD (His).

AC. Anterior column.
AH. Anterior horn of gray matter.
AL. Alar lamina.
AMF. Antero-median fissure.
AR. Anterior nerve-root.
BC. Column of Burdach.
BL. Basal lamina.
E. Ependyma.
GC. Column of Goll.
LC. Lateral column.
MDL. Mid-dorsal lamina.
MVL. Mid-ventral lamina.
PC. Early posterior column.
PH. Posterior horn of gray matter.
PMF. Postero-median fissure.
PR. Posterior nerve-root.

of the tube now appears on transverse section more or less lozenge-shaped, and it is at the lateral angles of the lozenge that this subdivision of the lateral wall becomes evident.

This subdivision is a fundamental one, being present in the brain-part as well as the

cord-part of the neural tube. By it the thick lateral wall is resolved into two longitudinal strips (the alar and basal laminæ), which extend along the whole length of the tube, and which present definite and precise relations with the entering and emerging roots of the various cranial and spinal nerves. Confining our attention to the spinal cord, the posterior nerve-root is seen to enter the alar lamina, whilst the anterior nerve-root takes origin within and emerges from the basal lamina.

Further Development of the Gray and White Matter of the Cord.—In the ventral part of the basal lamina the mantle layer thickens into a mass, which is readily recognised as the rudiment of the anterior horn of gray matter, and in this neuroblastic cells congregate in much larger numbers than elsewhere. Further, these neuroblastic cells begin to arrange themselves into groups, and the axis-cylinder processes of a large proportion of them converge and form bundles of fibres, which penetrate into the peripheral layer, and finally pierce the external limiting membrane, to emerge as the fascicles of the anterior nerve-roots. Behind the anterior horn the mantle layer still remains very thin, and the neuroblasts are few in number. There is, therefore, at this stage no appearance of the posterior horn of gray matter. Many of the axons of the neuroblasts which occupy this region are seen curving forwards, and, after traversing the anterior horn, they find their way across the middle line in the mid-ventral lamina. In this manner is laid down, at a very early stage, the rudiment of the anterior white commissure of the cord.

The white matter of the anterior and lateral columns is gradually established by axons from various neuroblasts in different parts of the mantle layer, entering the peripheral reticular layer and taking a longitudinal course within it. The anterior horn is well coated with white matter, however, before the lateral column takes definite shape.

The posterior columns of white matter are formed in a totally different manner, viz. by the introduction into the cord of nerve-fibres from without. The fibres of the posterior nerve-roots coming from the spinal ganglia strike the outer surface of the alar lamina of the lateral wall of the neural tube, and, piercing the external limiting membrane, take a longitudinal course in the peripheral reticular layer. On cross section these fibres first appear as an oval bundle, which lies in the outer part of the alar lamina (Fig. 379 PC). This bundle is the rudiment of Burdach's column, and at first it has a somewhat loose connexion with the cord; but as the posterior horn of gray matter gradually takes shape, the bundle in question increases in volume, and, changing its position, comes to lie on the inner aspect of the posterior horn. The column of Goll gradually assumes form between the tract of Burdach and the postero-median septum. Later on the lateral and anterior columns are increased in bulk by the descent into them of the pyramidal tracts from the brain.

The gray matter, in the first instance, is chiefly massed in the basal lamina; but as the posterior columns of white matter begin to take shape it extends backward, and in the course of time the posterior horns are developed.

The manner in which the dendritic processes of the neuroblasts are developed has been sufficiently described (p. 447). The ensheathment, also, of the axons by medulla has been referred to, and the fact that the different tracts of fibres receive their medullary sheaths at different periods mentioned. It is now only necessary to state that the order of myelinisation of the several tracts is as follows:—(1) Fibres of the anterior nerve-roots; (2) tract of Burdach; (3) fibres in the basis-bundles; (4) tract of Goll; (5) direct cerebellar tract; (6) tract of Gowers; (7) pyramidal tracts (Kahler).

Development of the Median Fissures and of the Central Canal.—As the anterior horns of gray matter covered by the anterior columns of white matter increase in size, the anterior surface of the cord on either side of the mesial plane bulges forwards, and the antero-median fissure is produced as the natural result.

The manner in which the postero-median fissure comes into existence is not fully understood, but the majority of embryologists believe that it is produced by the approximation and fusion of the walls of the posterior part of the primitive cavity of the neural tube. The postero-median septum would thus appear to be formed of spongioblastic tissue.

If the above view of the formation of the postero-median fissure be correct, it must be evident that the central canal of the cord does not represent the whole of the primitive cavity of the early neural tube, but only the anterior portion of it.

Among those observers who do not hold that the central canal and posterior fissure have this mode of origin the most prominent is Professor A. W. Robinson, of Birmingham; and he has brought forward evidence which seems to indicate that it is doubtful if the fusion of the walls of the posterior part of the canal, referred to above, takes place. Certainly the arrangement of the ependymal elements of the postero-median septum, as seen in the preparations of Cajal and v. Lenhossek, are extremely difficult to understand on the fusion theory. They run in the

antero-posterior direction, whereas, if fusion has taken place, most of them would present a transverse arrangement, and thus lie at right angles to the postero-median septum.

THE BRAIN OR ENCEPHALON.

The **brain** is the enlarged and greatly modified upper part of the cerebrospinal nervous axis. It is surrounded by the same membranes that envelop the spinal cord (viz. the dura mater, the arachnoid mater, and the pia mater), and it almost completely fills up the cavity of the cranium. So closely, indeed, is the skull capsule moulded upon the brain that the impress of the latter is almost everywhere evident upon the deep surface of the cranial wall. The relations, therefore, of cranium to brain are totally different from those presented by the vertebral canal

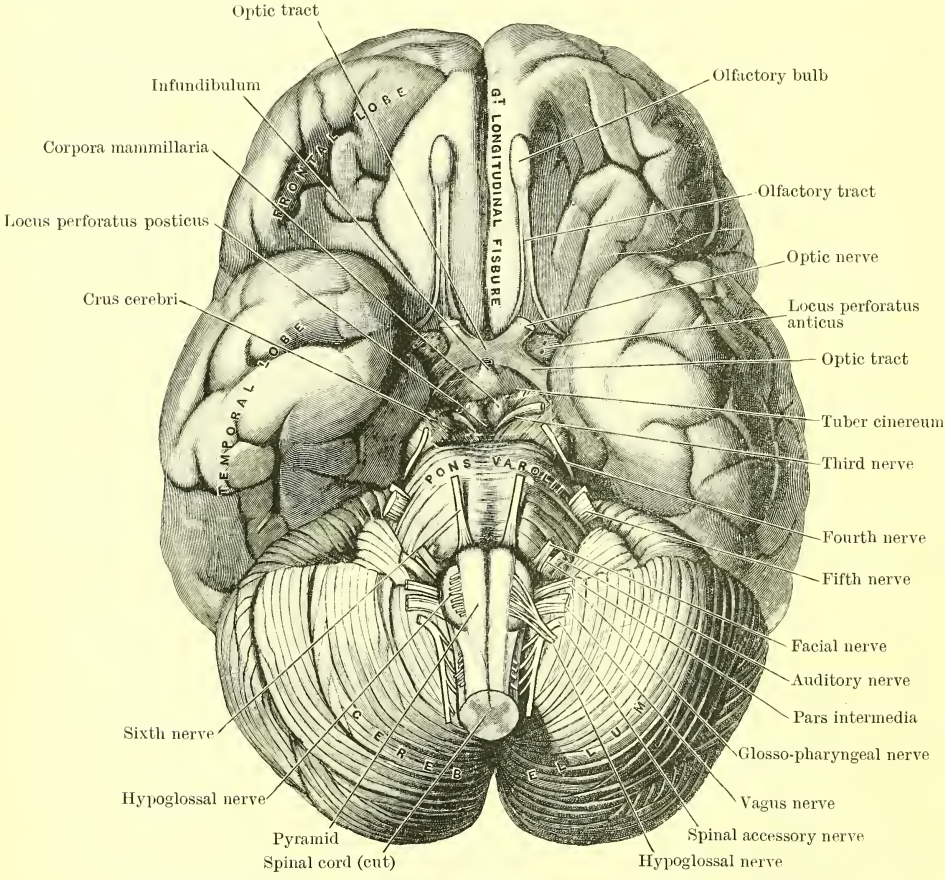


FIG. 380.—THE BASE OF THE BRAIN WITH THE CRANIAL NERVES ATTACHED.

to the spinal cord. As we have noted, the cord occupies only a part of its bony case; and there is not only a wide and roomy space between the arachnoid mater and pia mater, but also an interval of some width between the dura mater and the walls of the vertebral canal.

General Appearance of the Brain.—When viewed from above the brain presents an ovoid figure, the broad end of which is directed backwards. Its greatest transverse diameter is usually found in the neighbourhood of that part which lies between the two parietal eminences of the cranium. The only parts which are visible when the brain is inspected from this point of view are the two convoluted **cerebral hemispheres.** These present an extensive convex surface, which is closely applied to the deep aspect of the cranial vault, and are separated from each other by a deep median cleft, termed the **great longitudinal fissure,** which extends from the front to the back of the brain.

The inferior aspect of the brain is usually termed the "base." It presents an uneven and irregular surface, which is more or less accurately adapted to the inequalities on the floor of the cranium. Upon this aspect of the brain some of its main subdivisions may be recognised. Thus behind is seen the short cylindrical portion, called the **bulb** or **medulla oblongata**, through which, at the foramen magnum, the brain becomes continuous with the spinal cord. The bulb lies on the ventral aspect of the cerebellum, and occupies the vallecula or hollow which intervenes between the two cerebellar hemispheres. The **cerebellum** is a mass of considerable size which is placed below the hinder portions of the two cerebral hemispheres. It is easily recognised on account of the closely-set, curved, and parallel fissures which traverse its surface and give it a foliated appearance. Above the medulla, and in close connexion with it, is a prominent white elevation called the **pons Varolii**. Immediately in front of the pons there is a deep hollow or recess. This is bounded behind by the pons Varolii, on either side by the projecting temporal lobe of the cerebral hemisphere, and in front by the orbital portions of the frontal lobes of the cerebral hemispheres. Passing out from either side of the fore-part of this recess is the deep Sylvian fissure which intervenes between the pointed and projecting extremity of the temporal lobe and the frontal lobe of the cerebrum, whilst in the middle line in front the great longitudinal fissure, which separates the frontal portions of the cerebral hemispheres, opens into it.

Within the limits of this deep hollow, in the base of the brain, two large rope-like strands, the **crura cerebri**, may be seen issuing from the upper aspect of the pons Varolii. Placed close together as they emerge from the pons, these crura diverge as they proceed upwards and forwards, and finally each disappears by plunging into the corresponding side of the cerebrum. Turning round the outer side of each crus, where it enters the cerebrum, a flattened band termed the **optic tract** may be observed. These bands converge in the fore-part of the hollow, and are finally joined together by a short commissural portion, termed the **optic chiasma**. The **optic nerve** is continued forwards and outwards, on either side, from the chiasma and tract.

The crura cerebri, the optic tracts, and the optic chiasma enclose a deep rhomboidal or lozenge-shaped interval on the base of the brain, which is termed the **interpeduncular space**. Within the limits of this area the following parts may be seen as we pass from behind forwards: (1) the locus perforatus posticus; (2) the corpora mammillaria: (3) the tuber cinereum and the stalk of the pituitary body.

At its posterior angle, immediately in front of the pons Varolii, the interpeduncular space is very deep and is floored by a layer of gray matter, which is perforated by numerous small apertures. This is the **locus perforatus posticus**. Through the apertures which are dotted over its surface the small postero-mesial basal branches of the posterior cerebral artery enter the brain.

The **corpora mammillaria** are two small white pea-like eminences placed side by side in front of the locus perforatus posticus.

The **tuber cinereum** is a slightly raised field of gray matter, which occupies the interval between the anterior portions of the optic tracts in front of the corpora mammillaria. Springing from the fore-part of the tuber cinereum, immediately behind the optic chiasma, is the **infundibulum**, or the stalk which connects the pituitary body with the base of the brain.

Outside the limits of the fore-part of the interpeduncular space there is on either side a small depressed triangular field of gray matter, which leads outwards into the Sylvian fissure. It is perforated by the antero-mesial and the antero-lateral groups of basal arteries, and receives the name of the **locus perforatus anticus**.

General Connexions of the Several Parts of the Brain.—The medulla oblongata, the pons Varolii, and the cerebellum occupy the posterior cranial fossa, and they are separated from the cerebral hemispheres which lie above them by a partition of dura mater, termed the tentorium cerebelli. Further, they surround a cavity, a portion of the primitive cavity of the early neural tube, which is termed the **fourth ventricle** of the brain, and they all stand in intimate connexion with each other. The medulla is for the most part carried upwards into the pons

Varolii; but at the same time two large strands from its dorsal aspect, termed the restiform bodies, are prolonged into the cerebellum, and constitute its **inferior peduncles,** or the chief bonds of union between the medulla and the cerebellum. The pons Varolii has large numbers of transverse fibres entering into its composition, and the great majority of these are gathered together on either side in the form of a large rope-like strand. This plunges into the corresponding hemisphere of the cerebellum, and constitutes its **middle peduncle.**

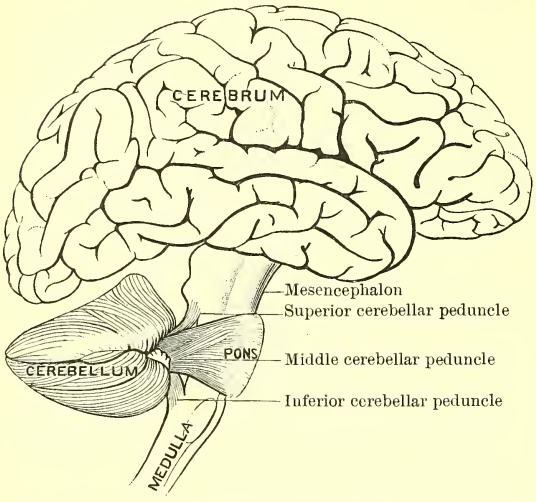


FIG. 381.—SCHEMA, showing the connexions of the several parts of the brain.

The cerebrum, which forms the great mass of the brain, occupies the anterior and middle cranial fossæ, and extends backwards into the occipital region above the tentorium and the cerebellum. The greater part of the cerebrum is formed by the cerebral hemispheres, which are separated from each other in the mesial plane by the great longitudinal fissure. At the bottom of this fissure is the **corpus callosum,** a broad commissural band which connects the two hemispheres with each other. Each hemisphere is hollow, the cavity in its interior being termed the **lateral ventricle** of the brain. Between and below the cerebral hemispheres, and almost completely concealed by them, is the **inter-brain** or **diencephalon.** The principal parts forming this portion of the brain are two large masses of gray matter, termed the **optic thalami.** Between these is the **third ventricle** of the brain—a deep narrow cavity occupying the mesial plane. The third ventricle communicates with the lateral ventricles by two small apertures, called the **foramina of Monro.**

The cerebrum is connected with the parts in the posterior cranial fossa (pons Varolii, cerebellum, and bulb) by a narrow stalk called the **mid-brain,** or **mesencephalon.** The mid-brain is built up of the **crura cerebri,** passing from the pons Varolii to the cerebrum; the **corpora quadrigemina,** forming its dorsal part; and the **superior cerebellar peduncles,** proceeding from the cerebellum to the cerebrum. It is tunnelled by a narrow passage, the **aqueduct of Sylvius,** which extends between the fourth and third ventricles.

GENERAL OUTLINE OF THE DEVELOPMENT OF THE BRAIN.

The brain is developed from the expanded anterior portion of the primitive neural tube. In the section dealing with the general principles of Embryology it has been pointed out that this part of the neural tube is marked off by two constrictions into three primitive cerebral vesicles, which are termed respectively the hind-brain or rhombencephalon, the mid-brain or mesencephalon, and the fore-brain or prosencephalon.

Hind-brain or Rhombencephalon.—The hind-brain is the largest of the three primary expansions of the neural tube: indeed, it may be said that in the earlier stages of brain development it is larger than both of the other primary subdivisions taken together. The portion immediately adjoining the mid-brain is constricted, and is termed the **isthmus rhombencephali.** This is a very small part, forming the extreme upper end of the vesicle, and from its walls are developed the superior cerebellar peduncles and a thin lamina, which is stretched across the middle line between them, called the valve of Vieussens or the superior medullary velum. Immediately behind the isthmus the hind-brain expands suddenly, and then slowly and gradually tapers as it passes downwards towards the spinal cord part of the neural tube. Its junction with the latter is very early indicated by a sharp bend

in the tube, which is termed the **cervical flexure.** The large portion of hind-brain which extends from the isthmus to the cervical flexure is usually considered as being composed of two parts, viz. an upper portion, termed the metencephalon, and an inferior portion, called the myelencephalon.

From the **metencephalon** are derived the cerebellum and pons Varolii. The cerebellum arises by a thickening of the dorsal wall of this portion of the vesicle, whilst the pons is formed by a thickening of the lateral and ventral walls. The

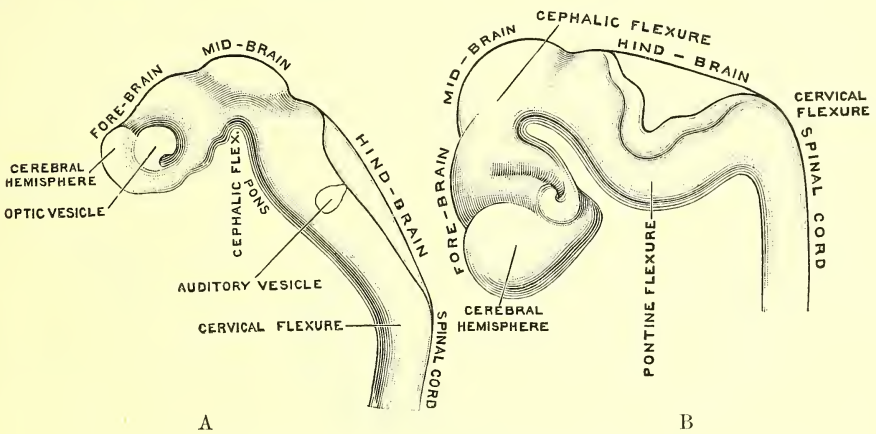


Fig. 382.—Two Stages in the Development of the Human Brain (after His).
A. Brain of an embryo of the third week. B. Brain of an embryo of five weeks.

myelencephalon gives origin to the bulb or medulla oblongata. This is chiefly formed by a thickening of the lateral walls of this part of the vesicle. These fall away from each other in an outward direction, and thus the ventral angle between them becomes greatly opened up. The growth which leads to the formation of the bulb appears, therefore, to take place chiefly on the ventral aspect of the vesicle. The dorsal wall remains thin and epithelial, and undergoes little or no development into nervous elements.

The cavity of the original hind-brain is retained in the adult brain as the fourth ventricle; and from what has been said regarding the development of the different portions of the wall of the primitive hind-brain, it will be seen that in its lower or medullary part its dorsal wall or roof, to a large extent, remains epithelial.

The parts of the adult brain which are derived from the rhombencephalon or hind-brain are those which lie below the tentorium cerebelli in the posterior cranial fossa of the skull.

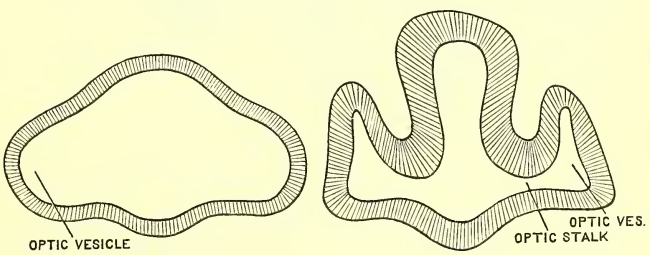


Fig. 383.—Two Cross Sections through the Fore-Brain.
A. Through the fore-brain of the early human embryo. B. Through the fore-brain and optic vesicles of a Lepidosteus embryo of eight days (after Balfour and Parker, modified).

Mesencephalon or Mid-brain.—The mid-brain takes a much more prominent part in the formation of the early primitive brain than it does in the construction of the adult brain. It forms a very small part of the adult brain, and constitutes a stalk of connexion between the parts which are developed from the walls of the rhombencephalon and those which are developed from the walls of the prosencephalon or fore-brain. The entire wall of the mid-brain is transformed into nervous tissue. Thus, by the special development of the dorsal section of the wall, the corpora quadrigemina are formed. The lateral and ventral sections of the wall undergo a still more marked degree of growth-thickening, and the result is the

formation of the two crura cerebri. The cavity of the mid-brain is retained as the narrow passage termed the aqueduct of Sylvius, which connects the third ventricle of the brain with the fourth ventricle.

Prosencephalon or Fore-brain.—In its early condition one of the leading peculiarities of the fore-brain is its great width. It extends outwards on either side for a considerable distance beyond the lateral walls of the mid-brain. These lateral expansions of the fore-brain are the **optic vesicles**, and at this stage they are in no way constricted off from the central part of the cavity (Fig. 383). Soon, however, the central portion of the fore-brain begins to expand upwards and forwards, whilst the terminal portions of the optic vesicles likewise undergo enlargement; and the result is, that the originally single chamber shows subdivision into three parts, viz. a central portion or fore-brain proper, and two expanded optic vesicles, which are joined to the lower parts of the lateral aspects of the fore-brain proper by two short constricted tubular passages termed the **optic stalks**.

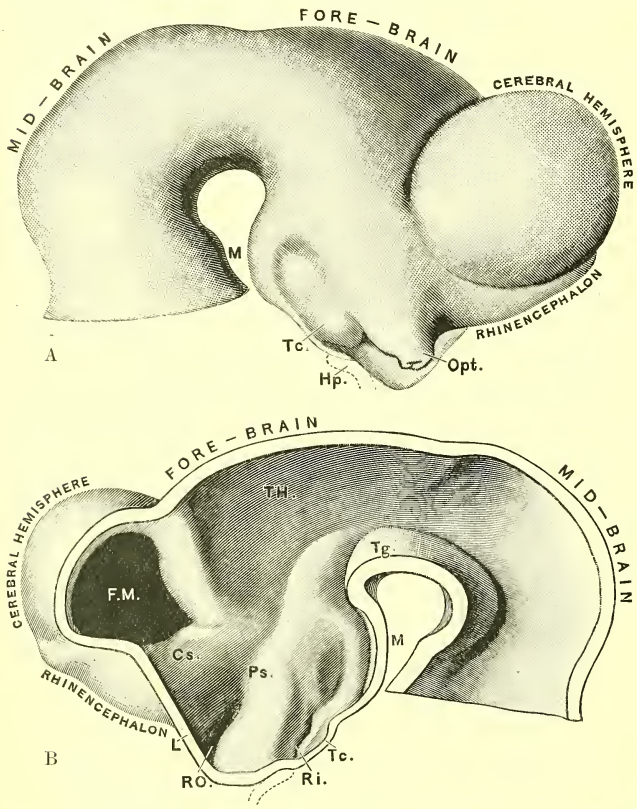


FIG. 384.—THE BRAIN OF A HUMAN EMBRYO IN THE FIFTH WEEK (from His).

A, Brain as seen in profile. B, Mesial section through the same brain. M, Mammillary eminence; Tc. Tuber cinereum; Hp, Hypophysis (pituitary diverticulum from buccal cavity); Opt, Optic stalk; TH, Optic thalamus; Tg, Tegmental part of mesencephalon; Ps, Pars subthalamica; Cs, Corpus striatum; FM, Foramen of Monro; L, Lamina terminalis; RO, Recessus opticus; Ri, Recessus infundibuli.

The optic vesicle and the optic stalk become ultimately transformed into the retina of the eye-ball and the optic nerve. The changes which lead to this result are detailed in the section dealing with the anatomy of the organ of vision.

The fore-brain undergoes a series of remarkable developmental changes, the most striking of which is the formation of the cerebral hemispheres. The terminal or fore-portion of the fore-brain, in the first instance, expands in a forward and downward direction, and from the upper and lateral aspects of the new portion of the vesicle thus formed the cerebral hemispheres bulge outwards in the form of two hollow pouches. The hinder original part of the fore-brain is termed the **thalamencephalon** or **diencephalon**, whilst the anterior part with the cerebral hemispheres, which protrude out from it, receives the name of **telencephalon**.

The side walls of the diencephalon become thickened into the two large masses of gray matter termed the optic thalami; the floor or ventral wall develops into those structures which occupy the interpeduncular space in the base of the brain (viz. the posterior perforated spot, the corpora mammillaria, and the tuber cinereum); whilst the roof or dorsal wall remains thin and epithelial, and undergoes no nervous development.

The hollow cerebral hemispheres soon outstrip all the other parts of the brain in their development. They expand not only in an upward and forward direction,

but chiefly in a backward direction; and by their excessive growth backwards they gradually come to overlie the diencephalon, the mesencephalon, and at last the parts derived from the rhombencephalon. It thus comes about that, when the adult brain is viewed from above nothing but the cerebral hemispheres are visible—all the other parts of the brain lie under cover of them.

At first the cavity of each cerebral hemisphere is connected with the cavity of the front portion of the fore-brain by an exceedingly short but relatively wide passage. This is the early condition of the **foramen of Monro**. The fore-part of the fore-brain is now seen to be bounded in front between the two hollow cerebral hemisphere-pouches by a narrow thin strip, which represents the extreme anterior wall of the neural tube, and consequently it receives the name of **lamina terminalis**. The cavity of the fore-brain not only in its hinder diencephalic part, but also in its anterior telencephalic part (*i.e.* the part from which the cerebral hemispheres bud out), persists as the third ventricle of the brain, whilst the cavities of the primitive cerebral hemispheres are represented in the adult by the lateral ventricles of the brain. The foramina of Monro, relatively much reduced in size, are preserved as narrow throats of communication between the lateral ventricles and the third ventricle. The olfactory lobes are formed as hollow outgrowths from the cerebral hemispheres.

Flexures of the Brain-tube.—At a very early period, and while the changes detailed above are being carried on, the cerebral portion of the neural tube becomes sharply bent upon itself at certain points. The first flexure which occurs is the **primary cephalic flexure**. It occurs in the region of the mesencephalon, and involves the entire head. The fore-brain becomes bent in a ventral direction round the fore-end of the notochord and the fore-gut, until the long axis of the fore-brain forms an acute angle with the long axis of the hind-brain and the ventral wall of the one comes to lie nearly parallel with the corresponding wall of the other. Through this curvature the mid-brain is considerably modified in form, and for a time it comes to occupy the most prominent and foremost part of the embryonic head.

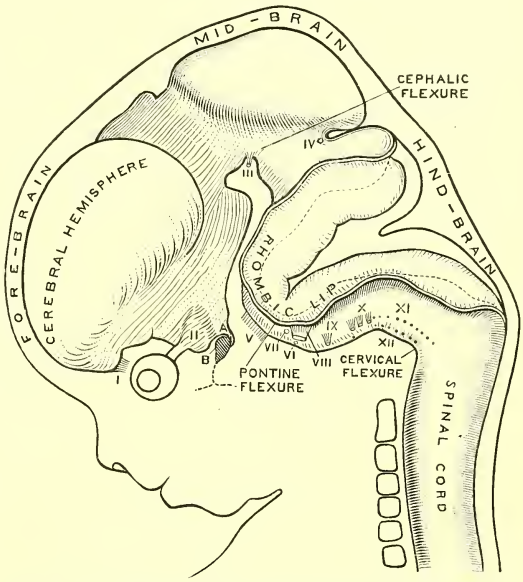


FIG. 385.—PROFILE VIEW OF THE BRAIN OF A HUMAN EMBRYO OF TEN WEEKS (His).

The various cranial nerves are indicated by numerals.

A, Cerebral diverticulum of pituitary body. B, Buccal diverticulum of pituitary body.

The primary cephalic flexure is soon followed by the **cervical flexure**. This occurs at the junction of the hind-brain with the spinal cord. Here the entire head is bent in a ventral direction, and at the end of the fifth week the flexure is so pronounced that the cerebral and spinal cord portions of the neural tube meet each other at a right angle (Fig. 385). In the later stages of development the cervical flexure becomes obliterated by the elevation of the head and the straightening of the neck of the embryo.

The third bend takes place in the region of the future pons Varolii (metencephalon), and is consequently termed the **pontine flexure**. It differs from the other flexures in being confined to the brain tube and in not in any way involving the entire head. Further, the bend is much more marked in the thick ventral wall than in the thin dorsal wall of the tube. The neural tube is doubled forwards on itself and the pons Varolii becomes developed in connexion with the summit of the curvature. In the further growth of the brain the pontine flexure becomes almost completely obliterated.

By reason of these curvatures the early brain assumes a sinuous, zigzag or S-shaped outline when viewed from the side, and the relationship of its various parts becomes materially altered. The essential factor at work in the production of the brain flexures is clearly the very unequal growth which takes place in different parts of the cerebral wall.

Basal and Alar Laminæ of His.—It has been pointed out that, in the development of the spinal cord, each of the thick lateral walls of the neural tube is marked off into a dorsal or alar and a ventral or basal lamina. This subdivision is also noticeable in the cerebral part of the neural tube, and the furrow on the inner aspect of the lateral wall, which indicates this subdivision, can be traced even in the adult brain throughout a considerable part of its length.

In the spinal cord the motor cells are gathered in the basal lamina in more or less continuous columns. In the brain the corresponding cells from which the efferent fibres of the cranial nerves are given off are also placed within the basal lamina, but they are arranged differently. They are collected together in disconnected clusters termed the motor nuclei, and they do not extend higher up than the mid-brain. No motor nuclei occur in the fore-brain. Indeed, the importance of the basal lamina diminishes as we pass from the lower to the higher parts of the brain.

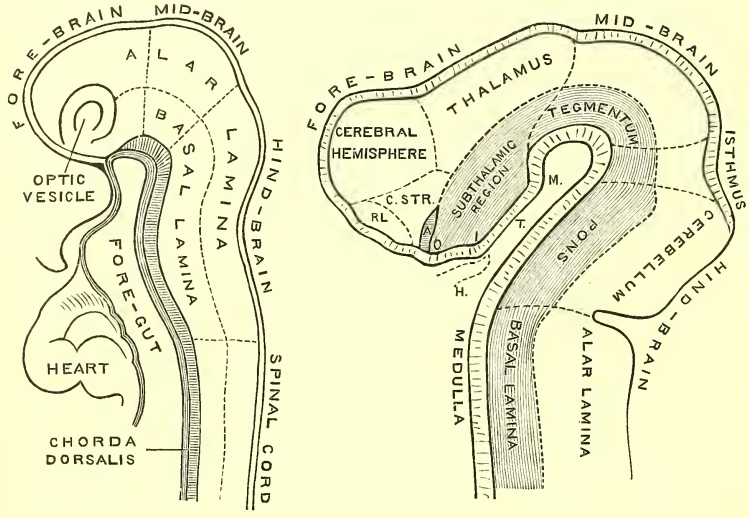


FIG. 386.—DIAGRAMS TO ILLUSTRATE THE ALAR AND BASAL LAMINÆ. In both cases the embryonic brain is represented in mesial section (His).

A. The different subdivisions of the brain are marked off from each other by dotted lines, and the dotted line running in the long axis of the neural tube indicates the separation of the alar from the basal lamina of the lateral wall.

B. Mesial section through the brain of a human embryo at the end of the first month. Dotted lines mark off the different regions and also the alar and basal laminæ from each other.

H, Buccal part of pituitary body; RL, Olfactory lobe; C.STR, Corpus striatum; A, Entrance to optic stalk; O, Optic recess; I, Infundibular recess; T, Tuber cinereum; M. Mammillary eminence.

In the rhombic or hind-brain the greater part of the medulla oblongata and of the pons Varolii is formed from the basal laminæ, whilst the cerebellum, with its superior and inferior cerebellar peduncles, is derived from the alar laminæ. In the mid-brain the crura cerebri are the derivatives of the basal laminæ, whilst the corpora quadrigemina are developed from the alar laminæ. In the fore-brain the subthalamic region and the optic vesicles are products of the growth of the basal laminæ, whilst the optic thalami and cerebral hemispheres spring from the alar laminæ.

The fact that the cerebellum and the cerebral hemispheres owe their origin to the alar laminæ is sufficient to show the predominant part which these laminæ play in brain development, and the higher we ascend in the animal scale the more pronounced does this predominance become.

The following table gives a summary of the various developmental processes which have been described in the foregoing pages:—

Encephalon or Brain	Rhombencephalon or Hind-brain (posterior cerebral vesicle)	Myelencephalon	Bulb or medulla oblongata Lower part of the fourth ventricle
		Metencephalon	Cerebellum Pons Varolii Upper part of the fourth ventricle
		Isthmus rhombencephali (narrow constricted part immediately adjoining the mesencephalon)	Superior cerebellar peduncles Valve of Vieussens
	Mesencephalon or Mid-brain (middle cerebral vesicle)	Mesencephalon or Mid-brain	Corpora quadrigemina Crura cerebri Aqueduct of Sylvius
	Prosencephalon or Fore-brain (anterior cerebral vesicle)	Thalamencephalon or Diencephalon	Optic thalami Subthalamic tegmental regions Pituitary and pineal bodies Structures in interpeduncular space Optic nerve and retina Hinder part of the third ventricle
		Telencephalon	Cerebral hemispheres Olfactory lobes Lateral ventricles Foramina of Monro Anterior portion of the third ventricle

THE PARTS OF THE ENCEPHALON DERIVED FROM THE HIND-BRAIN.

MEDULLA OBLONGATA OR BULB.

The **medulla oblongata** or **bulb** is the continuation upwards of the spinal cord. It is not more than one inch in length, and it may be regarded as beginning at the decussation of the pyramidal tracts, which takes place about the level of the foramen magnum. From this it proceeds upwards in a very nearly vertical direction, and ends at the lower border of the pons Varolii. At first its girth is similar to that of the cord, but it rapidly expands as it approaches the pons, and consequently it presents a more or less conical form. Its ventral surface lies behind the grooved surface of the basilar portion of the occipital bone, whilst its dorsal surface is sunk into the vallecula of the cerebellum. The medulla oblongata is a bilateral structure, and this is indicated on the surface by a continuation upwards of the antero-median and postero-median fissures of the cord on the ventral and dorsal aspects of the medulla.

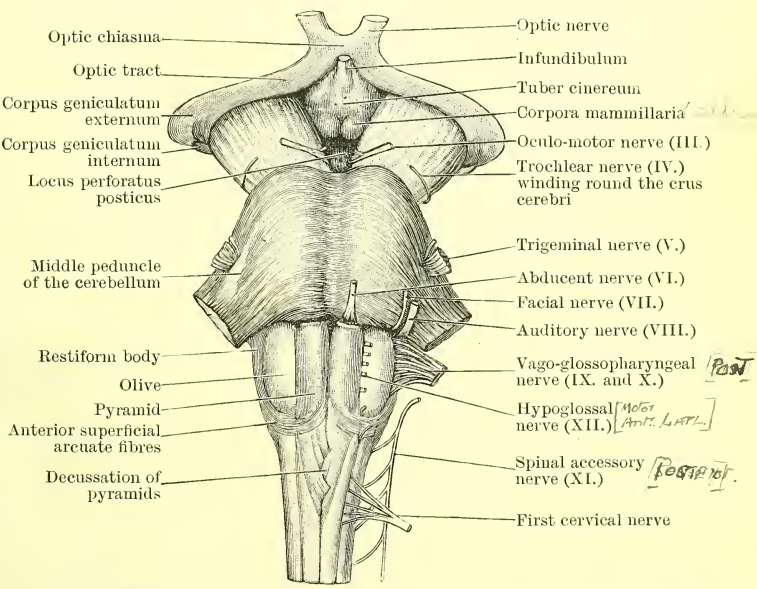


FIG. 387.—FRONT VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

The **antero-median groove** (fissura mediana anterior), as it passes from the cord on to the medulla, is interrupted at the level of the foramen magnum by several strands of fibres, which cross the mesial plane from one side to the other. This intercrossing is termed the decussation of the pyramids. Above this level the furrow is carried upwards to the lower border of the pons, but is often rendered very shallow by numerous superficial arcuate fibres which emerge upon the surface between its lips and then curve outwards to reach the hinder part of the medulla. At the lower margin of the pons Varolii it expands slightly and ends in a blind pit, which receives the name of the **foramen cæcum** of Vicq d'Azyr. The **postero-median fissure** (fissura mediana posterior) is only carried up on the lower half of the medulla. As it ascends it rapidly becomes shallower, and, halfway up, the central canal of the cord opens on the dorsal surface of the medulla. At this point the lips of the postero-median fissure are thrust apart from each other and constitute the boundaries of a triangular field, which is thus opened up on the dorsal aspect of the medulla. This triangular field is the lower part of the **fossa rhomboidalis**, or the floor of the fourth ventricle of the brain. The lower half of the medulla, containing as it does the continuation of the central canal of the cord, is frequently termed the **closed part of the medulla**; the upper half, above the opening of the canal, which by its dorsal surface forms the lower part of the floor of the fourth ventricle, is then called the **open part of the medulla.**

Deferring for the present the examination of the medullary part of the floor of the fourth ventricle, the appearance presented by the surface of each side of the medulla, from the antero-median fissure in front to the postero-median fissure and the lateral limit of the floor of the fourth ventricle behind, may now engage our attention. In the spinal cord the corresponding surface area is divided into three districts or columns by the emerging motor roots and the entering sensory roots of the spinal nerves. Of these the latter enter along the bottom of the postero-lateral groove, whilst the motor fascicles are spread over a relatively broad surface area and have no groove in connexion with their emergence from the cord. In the case of the medulla corresponding rows of nerve-fascicles enter and emerge from the surface of each side. The efferent fascicles are the root-bundles of the hypoglossal nerve, and they carry up the line of the anterior nerve-roots of the cord. In one respect, however, they differ: they emerge in linear order and along the bottom of a distinct furrow, termed the **antero-lateral furrow**, which proceeds upwards on the surface of the medulla. The fascicles which carry up the line of the posterior nerve-roots on the surface of the medulla are the root-bundles of the spinal accessory, the vagus, and the glosso-pharyngeal nerves. These are attached along the bottom of a furrow which is the direct continuation upwards of the postero-lateral furrow of the cord, and therefore receives the name of the **postero-lateral furrow** of the medulla. The root-bundles

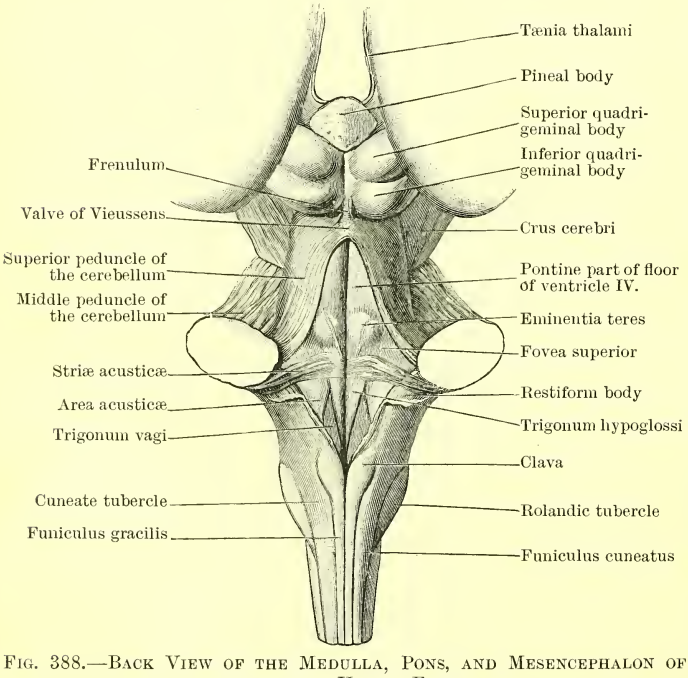


FIG. 388.—BACK VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

of these nerves differ, however, in so far that they are not all composed of afferent fibres springing from ganglionic cells placed without and entering the medulla. Certain of them are purely efferent (spinal accessory roots), whilst others likewise contain a considerable number of efferent fibres, and are therefore to be regarded as mixed roots.

By the postero-lateral and the antero-lateral grooves, and also by the two rows of nerve fascicles attached along the bottom of these furrows, the surface of the medulla on each side is divided into three districts, viz. an anterior, a lateral, and a posterior, similar to the surface areas of the three columns on the side of the cord. Indeed, at first sight, they appear to be a direct continuation upwards of these three portions of the cord; this is not the case, however, because the fibres of the three columns of the cord undergo a rearrangement as they proceed upwards into the medulla.

Anterior Area of the Medulla—Pyramid (pyramis).—The district between the antero-median fissure and the antero-lateral furrow, along the bottom of which the root-fascicles of the hypoglossal nerve issue from the medulla, receives the name of the pyramid. An inspection of the surface is sufficient to show that the pyramid is composed of a compact strand of longitudinally directed nerve-fibres. Tapering below, it expands and assumes a prominent appearance as it is traced upwards, and, finally reaching the lower border of the pons Varolii, it becomes slightly constricted and disappears from view by plunging into that portion of the brain. The two pyramids, separated from each other by the antero-median furrow, are the great motor strands of the medulla.

Although the pyramid at first sight appears to be continuous with the anterior column of the cord, only a very small proportion of the fibres contained in the latter are derived from the pyramid. This at once becomes manifest when the lips of the antero-median fissure are thrust apart at the place of junction between the cord and the medulla. The pyramid is then seen to divide at this level into two parts, viz. a small portion composed of a variable number of the outermost fibres of the pyramid, termed the **direct pyramidal tract**, and a much larger portion situated next the antero-median fissure, called the **crossed pyramidal tract**. The direct pyramidal tract is continued down into the anterior column of the cord, and in this it takes up a mesial position next the antero-median fissure. The crossed pyramidal tract is broken up into three or more coarse bundles, which sink backwards and at the same time cross the mesial plane, to take up a position in the posterior part of the opposite lateral column of the cord. The term **decussation of the pyramids** (decussatio pyramidum) is applied to the intercrossing of the corresponding bundles of the crossed pyramidal tracts of opposite sides.

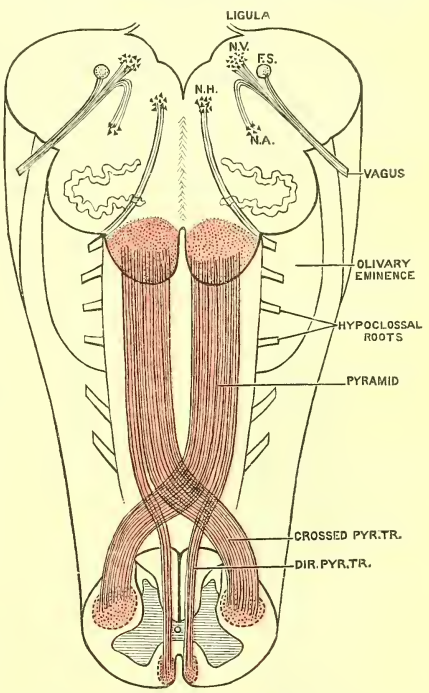


FIG. 389.—DIAGRAM OF THE DECUSSATION OF THE PYRAMIDS (modified from van Gehuchten).

NH, Nucleus hypoglossi; NV, Vago-glosso-pharyngeal nucleus; FS, Fasciculus solitarius; NA, Nucleus ambiguus.

The direct pyramidal tract is, therefore, the only part of the pyramid which has a place in the anterior column of the cord. The much larger part of this column, termed the anterior basis-bundle, as it is traced up into the medulla is seen to be thrust aside by the decussating bundles of the crossed pyramidal tract. It thus comes to occupy a deep position in the substance of the medulla behind and to the outer side of the pyramid.

Lateral Area of the Medulla.—This is the district on the surface of the medulla

which is included between the two rows of nerve-roots, viz. the hypoglossal roots in front, and the root-bundles of the spinal accessory, the vagus, and the glosso-pharyngeal nerves behind. It presents a very different appearance in its upper and lower parts. In its lower portion it simply appears to be a continuation upwards of the lateral area of the cord; in its upper part a striking oval prominence bulges out on the surface of the medulla, and receives the name of the **olivary eminence.**

The lower part of this district, however, is very far from being an exact counterpart of the lateral column of the cord. The large crossed pyramidal tract is no longer present, seeing that it forms in the medulla the greater part of the pyramid of the opposite side. Another strand of fibres, viz. the direct cerebellar tract, prolonged upwards in the lateral column of the cord, gradually leaves this portion of the medulla. This tract lies on the surface, and is frequently visible to the naked eye as a white band, which inclines obliquely backwards into the posterior district of the medulla to join its upper part, or in other words the restiform body. The remainder of the fibres of the lateral column of the cord, comprising the lateral basis-bundle and the tract of Gowers, are continued upwards in the lateral area of the medulla, and at the lower border of the olive the majority of these fibres disappear from the surface by dipping into the substance of the medulla under cover of that projection. A small proportion of the fibres, however, are retained on the surface and travel upwards towards the pons in the interval, which exists between the hinder border of the olive and the roots of the vagus and glosso-pharyngeal nerves.

The **olivary eminence** (oliva) is a smooth oval projection which bulges out from the upper part of the lateral area of the medulla. Its long axis is vertical and is about half an inch long. It marks the position of the subjacent **inferior olivary nucleus**, a flexuous lamina of gray matter (nucleus olivaris inferior), which is only separated from the surface by a very thin layer of superficial white matter.

Posterior Area of the Medulla.—In its lower half, this district is bounded behind by the postero-median fissure, and in its upper half by the lateral margin of the medullary part of the floor of the fourth ventricle of the brain. In front it is separated from the lateral area by the row of root-fascicles belonging to the spinal accessory, vagus, and glosso-pharyngeal nerves. As in the lateral area, we recognise a lower portion and an upper portion, which appear continuous but in reality are almost quite distinct from each other.

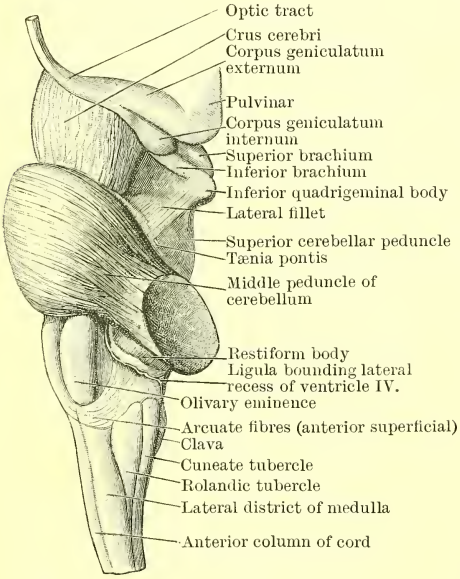


FIG. 390.—LATERAL VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

The lower part of the posterior area corresponds more or less closely with the posterior column of the cord. In the cervical part of the cord the posterior column is divided by the paramedian septum of pia mater into an inner column of Goll and an outer column of Burdach. These are prolonged upwards into the medulla, and in the lower part of the posterior area they stand out distinctly, and are separated from each other by a continuation upwards from the cord of the paramedian groove. In the medulla the inner of these strands is called the **funiculus gracilis**, whilst the outer one is designated the **funiculus cuneatus.** Each of these strands, when it reaches the level of the lower part of the floor of the fourth ventricle, ends in a slightly expanded bulbous prominence. The swollen extremity of the funiculus gracilis is called the **clava.** This is thrust aside from its neighbour of the opposite side by the opening up of the medulla to form the floor of the fourth ventricle, and the central canal of

the cord opens on the surface in the angle between the two clavæ. The bulbous end of the fasciculus cuneatus receives the name of the **cuneate tubercle** (tuberculum cinereum), but it is only in the fœtal or very young brain that it is well marked.

The elongated prominences formed on the surface of the medulla by these two strands and their enlarged extremities are, in a great measure, due to the presence of two elongated nuclei or collections of gray matter which make their appearance subjacent to the strands, and which gradually increase in bulk as they are traced upwards. These are termed respectively the **gracile** (nucleus funiculi gracilis) and **cuneate** (nucleus funiculi cuneati) **nuclei**, and it can be easily shown that as the gray matter increases in quantity the fibres of the two corresponding strands diminish in number by coming to an end in connexion with the cells of the subjacent nuclei. Indeed, it is doubtful if any of the fibres of the gracile and cuneate strands extend upwards beyond these nuclei.

But a third longitudinal elevation is also apparent on the surface of the lower part of the posterior area of the medulla. This is placed on the outer side of the funiculus cuneatus—between it and the posterior row of nerve-roots—and it has no counterpart in the posterior column of the cord. It is called the **funiculus of Rolando**, because it is produced by the substantia gelatinosa Rolandi, which caps the posterior horn, coming close to the surface and forming a bulging in this situation. The funiculus of Rolando is wedge-shaped in outline. Extremely narrow below, it widens as it is traced upwards, and finally ends in an expanded extremity called the **tubercle of Rolando** (tuberculum Rolandi). A thin layer of white matter, composed of longitudinally arranged fibres, is spread over this district, and separates the substantia Rolandi from the surface. These fibres constitute the spinal root of the fifth or trigeminal nerve, which here assumes a superficial position as it descends in the medulla.

The **restiform body** (corpus restiforme) forms the upper part of the posterior area of the medulla. It lies between the floor of the fourth ventricle and the roots of the vagus and glosso-pharyngeal nerves. It is a large and prominent rope-like strand, which inclines upwards and outwards, and then finally takes a turn backwards and enters the cerebellum. It forms the great link of connexion between the cerebellum on the one hand and the medulla and spinal cord on the other, and consequently it also receives the name of the **inferior cerebellar peduncle**. At the same time it must be understood that it is not formed by fibres which are prolonged into it from the funiculus cuneatus and funiculus gracilis of the medulla. It is true that a surface inspection of the medulla might very naturally lead the observer to this supposition, because there is no sharp line of demarcation marking it off from the tubercles of these strands. Such a conclusion, however, would be altogether erroneous, because it would appear that none of the fibres of the posterior columns of the cord are carried beyond the gracile and cuneate nuclei of the medulla. A study of the surface of the medulla yields some important information regarding the constitution of the restiform body. Thus the direct cerebellar tract from the lateral column of the cord can be traced into it, and large numbers of fibres which take a curved course on the surface of the medulla may likewise be followed into it. These are the superficial arcuate fibres. Numerous other fibres enter the restiform body on its deep aspect, but these will be studied at a later stage.

Superficial Arcuate Fibres (fibræ arcuatæ externæ).—These fibres enter into the constitution of the restiform body, and they may be regarded as consisting of two sets, viz. the anterior superficial arcuate fibres and the posterior superficial arcuate fibres, both of which present this feature in common that they run on the surface of the medulla.

The **anterior superficial arcuate fibres** are more particularly seen in the neighbourhood of the olivary eminence, round the lower border of which, and also over the surface of which, they may be observed coursing in the form of a number of coarse curved bundles. They vary greatly in number and in distinctness, and they are sometimes so numerous as to cover over almost entirely the eminence. An attentive examination will show that they come to the surface in the antero-median fissure between the pyramids, and also not unfrequently in the groove between the

pyramid and olive, or through the substance of the pyramid itself. The antero-median fissure in its upper part is often almost completely blocked up by these emerging fibres. The anterior superficial arcuate fibres reaching the surface of the medulla in this manner turn backwards, and the great majority enter the restiform body and form a considerable part of its outer portion.

The **posterior superficial arcuate fibres** arise in the cuneate and gracile nuclei, and enter the restiform body of the same side.

THE PONS VAROLII.

The **pons Varolii** is a marked white prominence on the basal aspect of the brain which is interposed between the medulla and the crura cerebri, and which lies in front of the cerebellum. It is convex from side to side, as well as from above downwards, and transverse streaks on its surface show that, superficially at least, it is composed of bundles of nerve-fibres which course transversely over it. On either side these transverse fibres are collected together in the form of a large compact strand, which sinks in a backward and outward direction into the white matter of the corresponding hemisphere of the cerebellum. This strand is termed the **middle peduncle of the cerebellum**, and the term "pons," applied to the entire structure, expresses in an admirable way the arch-like manner in which this portion of the brain bridges across between the two cerebellar hemispheres.

The *ventral surface* of the pons is in relation to the basilar process of the occipital bone and the dorsum sellæ of the sphenoid bone. It presents a mesial groove (sulcus basilaris), which gradually widens as it is traced upwards, and in which the basilar artery lies. This mesial depression is produced by the prominence which is caused on either side by the passage of the pyramidal tract of fibres downwards through the pons. The **trigeminal** or fifth cranial nerve, with its large entering sensory root and its small emerging motor root, is attached to the side of the ventral aspect of the pons, nearer its upper than its lower border. It is usual to restrict the term "pons" to that portion of the structure which lies between the two trigeminal nerves, and to apply the designation of middle cerebellar peduncle to the part which extends beyond the nerve into the hemisphere of the cerebellum. The sixth or **abducent nerve**, the seventh or **facial nerve**, and the eighth or **auditory nerve** are attached to the brain at the lower border of the pons. The sixth emerges at the outer border of the pyramid, the seventh immediately in front of the restiform body, whilst the auditory nerve reaches the brain close to the facial nerve, on the ventral aspect of the restiform body.

The whole of the medulla enters the *lower aspect* of the pons, and, with the exception of the restiform bodies, its constituent parts are, to a large extent, carried up within it. The crura cerebri emerge from its *upper aspect.*

The *dorsal surface* of the pons looks backwards towards the cerebellum, and presents a triangular area covered with gray matter, which forms the upper part of the anterior wall or floor of the fourth ventricle. This area is directly continuous below with the medullary part of the floor of the fourth ventricle, and is bounded on either side by a band of white matter termed the **superior peduncle of the cerebellum.**

Superior Cerebellar Peduncles (brachia conjunctiva).—These are hidden from view by the upper part of the cerebellum, under cover of which they lie. They emerge from the lateral hemispheres of the cerebellum, and, as they proceed upwards on the dorsal aspect of the pons, they converge towards each other until, at the level of the inferior corpora quadrigemina, the inner margins of the two peduncles almost become contiguous (Fig. 388, p. 482). At first they form the lateral boundaries of the upper part of the fourth ventricle; but, as they ascend and approach closer to each other, they gradually come to overhang that cavity and thus enter into the formation of its roof. They disappear from the surface by dipping under cover of the quadrigeminal bodies and entering the substance of the mesencephalon.

Valve of Vieussens or the Superior Medullary Velum (velum medullare anterius).—Filling up the triangular interval between the two superior cere-

bellar peduncles, and stretching across from the inner and free margin of the one to the corresponding margin of the other, is a thin layer of white matter which completes the roof or dorsal wall of the upper part of the fourth ventricle, and receives the name of the superior medullary velum. When traced downwards, it is seen to be carried with the superior peduncles into the white matter of the cerebellum. Spread out on its dorsal surface is a small, thin, tongue-shaped prolongation of gray matter from the cortex of the cerebellum, which is termed the **lingula**, whilst issuing from its substance close to the inferior quadrigeminal bodies are the two **fourth** or **trochlear cranial nerves**.

Fourth Ventricle of the Brain (ventriculus quartus).—The fourth ventricle is somewhat rhomboidal in form. Below, it tapers to a point and becomes continuous with the central canal of the cord; above, it narrows in a similar manner and is continued into the aqueduct of Sylvius, which tunnels the mesencephalon. The posterior wall is termed the **roof** and is concealed by the cerebellum. The anterior wall is called the **floor** and is formed by the dorsal surfaces of the medulla and pons. On either side a long, curved and narrow prolongation of the ventricular cavity is carried outwards from its widest part and curves round the upper part of the corresponding restiform body. This is termed the **lateral recess**. The roof of the cavity is very thin and intimately connected with the cerebellum. It is better, therefore, to defer its description until that part of the brain has been studied.

Floor of the Fourth Ventricle (fossa rhomboidea).—In its lower part the floor of the fourth ventricle is formed by the dorsal surface of the open part of the

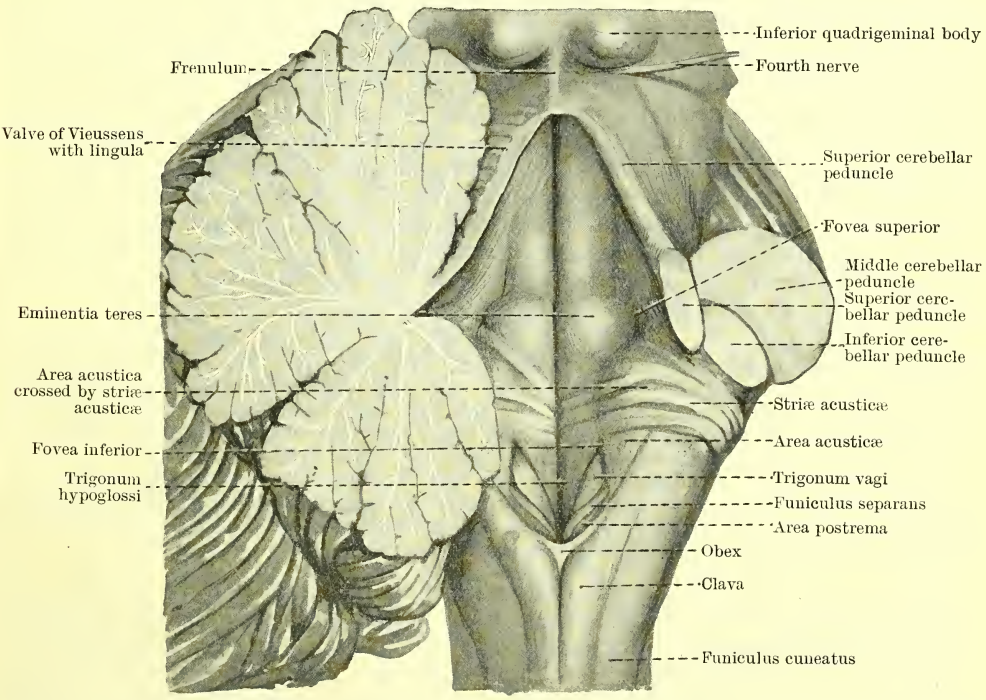


FIG. 391.—FLOOR OF THE FOURTH VENTRICLE. On the right side the right half of the cerebellum has been removed by cutting through its three peduncles and dividing it in the mesial plane. On the left side the left half of the cerebellum is drawn over to the left so as to expose fully the floor of the ventricle.

medulla, whilst in its upper part it is formed by the dorsal surface of the pons Varolii (Fig. 388, p. 482). The area thus constituted is lozenge-shaped, its widest part being opposite the upper ends of the restiform bodies or inferior peduncles of the cerebellum. A thick layer of gray matter, continuous with that which surrounds the central canal of the cord, is spread out like a carpet over the ventricular floor, and covering this is the usual ependymal layer, which lines all the ventricles of the brain. The area is circumscribed by definite lateral boundaries.

Thus, *below* it is bounded on either side by the clava, the cuneate tubercle, and the restiform body; whilst *above* the lateral limits are formed by the superior cerebellar peduncles.

The floor of the fourth ventricle is divided into two lateral and symmetrical portions by a median groove. Its lower narrow pointed portion between the two clavæ receives the name of the **calamus scriptorius**, from its fancied resemblance to the point of a pen. Crossing each half of the floor, at its widest part, are several more or less conspicuous bundles of fibres termed the **striæ acusticæ**. They appear to emerge from the mesial groove and they are carried outwards over the floor of the ventricle in the region between its upper pontine and lower medullary portions. The striæ acusticæ exhibit a large amount of variation in different individuals both in their degree of prominence and also in the direction which they pursue. As a general rule they proceed towards the upper part of the restiform body, where they are connected with the cochlear nuclei. Except for this break on the surface, the medullary and pontine portions of the floor of the fourth ventricle are quite continuous with each other.

On the lower medullary district of the ventricular floor a small triangular depression, placed immediately below the striæ acusticæ, catches the eye. This is termed the **fovea inferior.** It is shaped somewhat like an arrow-head. The apex or point looks towards the striæ, whilst the lateral angles of the base are prolonged downwards in the form of diverging grooves (Fig. 391, p. 487). Of these, the inner groove runs towards the opening of the central canal at the calamus scriptorius, whilst the outer groove runs towards the lateral boundary of the floor. In this manner the portion of the floor which lies below the striæ acusticæ is mapped out into three triangular areas. The mesial subdivision is slightly elevated and is termed the **trigonum hypoglossi,** because subjacent to the inner part of this area is the nucleus of origin of the hypoglossal or twelfth cranial nerve. The intermediate area between the two diverging grooves which proceed from the base of the fovea inferior is the **trigonum vagi** (ala cinerea), so called because the nucleus of the vagus or tenth and the glosso-pharyngeal or ninth cranial nerves lies subjacent to it. The external area is the **trigonum acustici.** The base of this area is directed upwards and runs continuously into an eminence—the **acustic area** (area acustica)—over which the striæ acusticæ pass. Subjacent to this district of the floor of the ventricle lies the large terminal chief nucleus of the vestibular division of the auditory or eighth cranial nerve.

A close inspection of the medullary part of the floor of the fourth ventricle in the region of the calamus scriptorius will show that the base of the trigonum vagi is separated from the inner margin of the clava by a narrow lanceolate strip of the ventricular floor, to which Retzius has given the name of **area postrema.** Beneath this area is some vascular tissue (Streeter), and marking it off on its upper and inner aspect from the base of the trigonum vagi there is a translucent cord-like ridge called the **funiculus separans.**

When the floor of the ventricle is examined under water with a magnifying glass, the trigonum hypoglossi is seen to consist of a narrow inner strip which corresponds to the hypoglossal nucleus, and a wider lateral part which has been shown to be the surface representation of another nucleus termed the nucleus intercalatus (Streeter).

On the part of the floor of the ventricle which lies above the striæ acusticæ, and which corresponds to the dorsal surface of the pons, there is also a slight depression termed the **fovea superior.** Between it and the median groove is a marked prominence called the **eminentia teres.** Inferiorly this elevation passes downwards and becomes continuous with the trigonum hypoglossi, whilst above it is carried upwards towards the opening of the aqueduct of Sylvius. In both directions it becomes gradually less prominent, but still it forms a distinct elongated elevation, which stretches along the whole length of the median groove. As already stated, the **area acustica** extends upwards into the pontine part of the ventricular floor and forms an elevated region in the outermost part of its widest portion, below and to the outer side of the fovea superior. Proceeding upwards from the fovea superior to the opening of the Sylvian aqueduct there is a shallow depression termed the **locus cæruleus,** seeing that it usually presents a faint slate-gray colour. When the ependyma is scraped away from the surface of this part of the floor, the colour is seen to be due to the **substantia ferruginea,**—a name applied to a linear group of

strongly pigmented cells, which lies in the lateral part of the gray matter covering this portion of the ventricular floor. When transverse sections are made through the upper part of the pons, the substantia ferruginea appears on the cut surface as a small black spot or dot.

INTERNAL STRUCTURE OF THE MEDULLA.

The internal structure of the medulla differs in a marked degree from that of the spinal cord; indeed, in its upper part it presents very little in common with the latter. The various strands of the cord either come to an end within the medulla or undergo changes in their relative position, whilst the gray matter is much modified and new masses are added. Like the cord, however, the medulla consists of two nearly symmetrical right and left halves. When transverse sections are made through it at different levels each lateral half is seen to be partly marked off from the other in the lower closed part of the medulla by the anterior and posterior median fissures, whilst in the upper open part of the medulla the subdivision is rendered evident in transverse sections by the presence of a distinct median

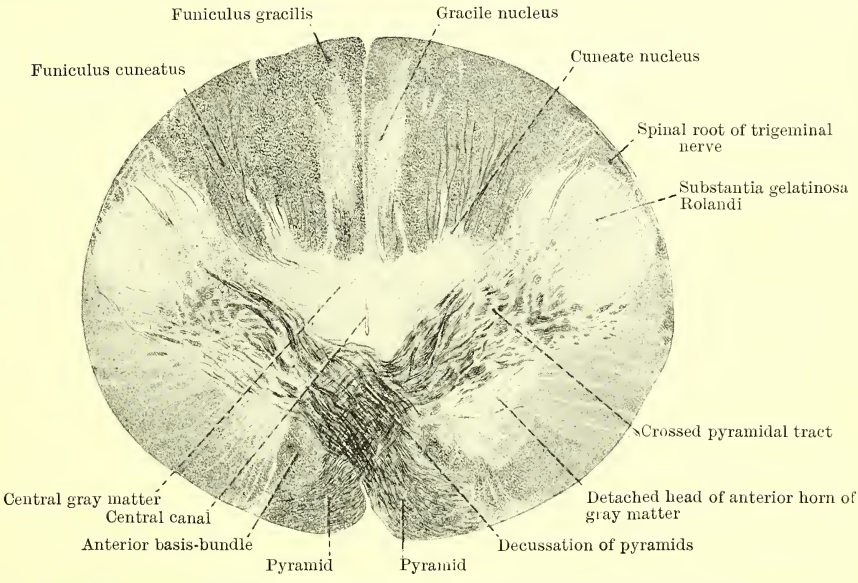


Fig. 392.—Section through the Lower End of the Medulla Oblongata of a Chimpanzee to show the Decussation of the Pyramids.

line, called the **raphe**, which occupies the mesial plane. The raphe is formed by the close intersection of fibres running in different directions and crossing from one side to the other.

Each half of the medulla is composed of: (*a*) strands of white matter; (*b*) gray matter; and (*c*) the formatio reticularis.

The **white matter**, as in the cord, is to a large extent disposed on the surface, and the gray matter in the interior; but in the upper open part of the medulla the gray matter comes to the surface on the dorsal aspect, and is spread out over that area which forms the medullary part of the floor of the fourth ventricle. In the cord the white matter, in the shape of massive longitudinal strands of fibres, forms a thick coating round the central gray matter. In the medulla the only massive longitudinal strands which are seen on the surface are the gracile and cuneate strands (until they become absorbed by the subjacent nuclei), the inferior cerebellar peduncles or restiform bodies and the pyramidal tracts. Elsewhere the coating of white matter is thin, and in certain places is composed chiefly of the superficial arcuate fibres. New longitudinal strands, however, take shape within the medulla, and two of the most important are placed on either side of the median raphe.

The **gray matter** of the cord, as it is continued upwards into the medulla,

becomes greatly modified. A considerable part of it is broken up in the formatio reticularis, whilst the only portions which remain as compact masses in direct continuity with the gray matter of the cord are: (1) the thick layer which surrounds the central canal, and which, in the open part of the medulla, becomes spread out on the floor of the fourth ventricle; and (2) the substantia gelatinosa Rolandi. New masses of gray matter, which are not represented in the cord, and which in some cases appear in isolated clumps, are also added. The chief of these are the gracile and cuneate nuclei, the inferior olivary nuclei, and the arcuate or pyramidal nuclei.

The **formatio reticularis** is only feebly represented in the cord, but in the medulla it forms a very considerable part of its bulk. It is composed of gray matter coarsely broken up by fibres, which traverse it in different directions.

In the following detailed account of the internal structure of the medulla, it must be understood that the appearances described are such as are seen when successive transverse sections through the bulb are examined.

Decussation of the Pyramids and the Changes produced thereby.—As we pass under the microscope a series of successive transverse sections through the upper end of the cord and the lower end of the medulla, the most striking change which meets the eye is the decussation of the pyramids. The crossed pyramidal tract in the lateral column of the cord is seen to become looser in its formation; then coarse strands leave it, pass right through the anterior horn of gray matter, and, crossing the mesial plane, take up their position in the other side of the medulla, close to the antero-median fissure. Strands from the right crossed pyramidal tract alternate with corresponding strands from the left side, and the interval between the bottom of the antero-median furrow and the gray matter surrounding the central canal becomes filled up with a great mass of intercrossing bundles of fibres. When the decussation is completed the pyramid is seen to be composed of a solid and compact bundle of fibres, well marked off from the surrounding structures, which lies at the side of the antero-median fissure of the medulla.

As a rule the inner three-fourths of the pyramid is composed of fibres which, lower down in the opposite lateral column of the cord, form the crossed pyramidal tract, whilst the outer fourth of the pyramid proceeds downwards in the anterior column of the cord of the same side as the direct pyramidal tract. A considerable amount of variation, however, occurs in the proportion of fibres which is allotted to the formation of these two tracts of the cord. Sometimes the crossed pyramidal tract is much larger than usual, and then the direct pyramidal tract suffers a corresponding diminution in size. Cases indeed occur in which the entire pyramid enters into the decussation, and in these there is no direct pyramidal tract in the cord. Further, it is not uncommon to meet with variations of an opposite kind which lead to an increase of the direct pyramidal tract at the expense of the crossed tract. In the majority of cases the decussation appears to be symmetrical—the division of the pyramid at the lower end of the medulla being into parts of corresponding size on the two sides; in certain instances, however, the decussation is asymmetrical, and the corresponding pyramidal tracts on opposite sides of the cord are then unequal in size. Seeing that the direct pyramidal tracts undergo a gradual decussation in the anterior commissure, as they descend in the cord, the final result is the same, no matter what variations occur in the decussation at the lower part of the medulla.

The variations indicated above receive an additional interest when viewed in the light of comparative anatomy. It would appear that only in man and the anthropoid apes is the decussation of the pyramids in the lower part of the medulla incomplete. According to Sherrington, a direct pyramidal tract in the cord of the anthropoid apes stands in connexion with the arm-centre in the cerebral cortex. If this be the case in man it must likewise have other connexions as well, seeing that it is carried down the cord for a considerable distance beyond the level of the cord-segments which give motor fibres to the arm. In the lower apes a direct pyramidal tract does not seem to exist: the whole pyramid crosses over to the opposite side of the cord in the shape of the crossed pyramidal tract.

As we have noted, the decussating pyramidal bundles pass through the anterior horn of gray matter of the cord, and cut it into two portions (Figs. 392 and 395). The basal part remains in position on the anterior and lateral aspect of the central canal, and forms part of the thick layer of gray matter which surrounds it. The

detached head of the anterior horn is set free; and from the large multipolar cells which lie in its midst some of the fibres of the anterior root of the first cervical nerve, and also some of the root fibres of the spinal accessory nerve, take origin.

On proceeding up into the medulla another effect of the decussation of the pyramids is seen in the submergence from the surface of the strand of fibres which, in the anterior column of the cord, lies to the outer side of the direct pyramidal tract, and which receives the name of the anterior basis-bundle. While the decussation is going on the anterior basis-bundle is thrust aside, and, sinking from the surface, it takes up its position as a flattened band-like strand on the outer side of the gradually increasing pyramid (Fig. 393). When the decussation is completed, this strand is seen to lie close to the median plane on the dorsal aspect of the pyramid, where it is separated from its fellow of the opposite side by the median raphe alone (Fig. 394). In the upper part of the medulla it approaches still nearer to the dorsal surface and appears to form the greater part of a strand, which is termed the **posterior longitudinal bundle** (Figs. 397 and 398). The detached head of the anterior horn of gray matter of the cord, as it is traced upwards, is observed to cling closely to its original relationship with the anterior basis-bundle. It is applied to the outer side of this strand, and, gradually becoming smaller, finally disappears at the level of the lower part of the inferior olivary nucleus.

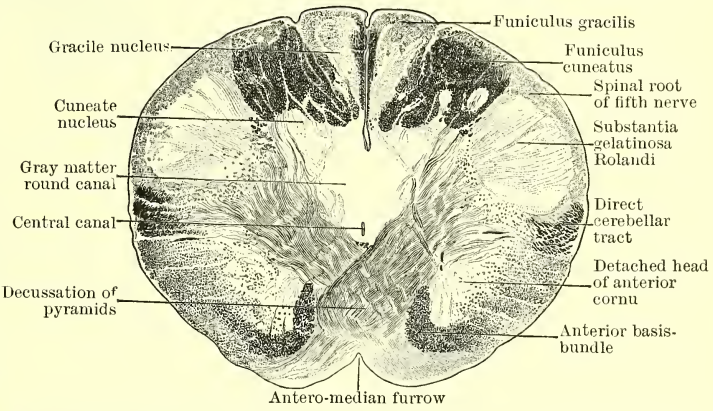


FIG. 393.—TRANSVERSE SECTION THROUGH LOWER END OF THE MEDULLA OF A FULL-TIME FŒTUS,

Treated by the Weigert-Pal method. The gray matter is bleached white, and the medullated tracts of fibres are black.

Cuneate and Gracile Strands, with their Nuclei.—As the funiculus gracilis and the funiculus cuneatus of the posterior column of the cord are traced up into the medulla they seem to increase in bulk, and in transverse sections they assume the form of massive wedge-shaped strands, quite distinct from each other. When the decussation of the pyramids is fully established they change their shape. They increase in width and lose considerably in depth, and consequently the transverse diameter of the area which they occupy becomes greater. As a result of this, and also owing to the removal of the crossed pyramidal tract from the lateral region of the cord immediately in front, the posterior horn of gray matter is gradually rotated forwards and comes to lie transversely and in the same straight line with its fellow of the opposite side (Figs. 393 and 395). The substantia gelatinosa Rolandi, at the same time, becomes increased in quantity and presents a horseshoe-shaped outline in transverse section. It clasps within its concavity the somewhat reduced head of the posterior horn, and forms with it a conspicuous circular mass of gray matter which lies close to the surface, and produces upon it the bulging termed the funiculus and tubercle of Rolando. The basal portion of the posterior horn of gray matter remains upon the dorsal and lateral aspect of the central canal, and forms a portion of the central gray mass of the closed part of the medulla; but very soon the neck of the horn, which at this level is greatly reduced owing to the absence of entering posterior nerve-roots, is invaded by bundles of fibres which traverse it in different directions and convert it into a formatio reticularis. By this means the rounded head of the posterior horn becomes cut off from the central gray matter, and from this point upwards it remains as an isolated gray column intimately associated with the spinal root of the trigeminal nerve.

The **gracile** and **cuneate nuclei** take shape before the decussation of the pyramids is fully completed (Fig. 395). The **gracile nucleus** appears in the form of a small irregular mass of gray matter in the interior of the funiculus gracilis, which

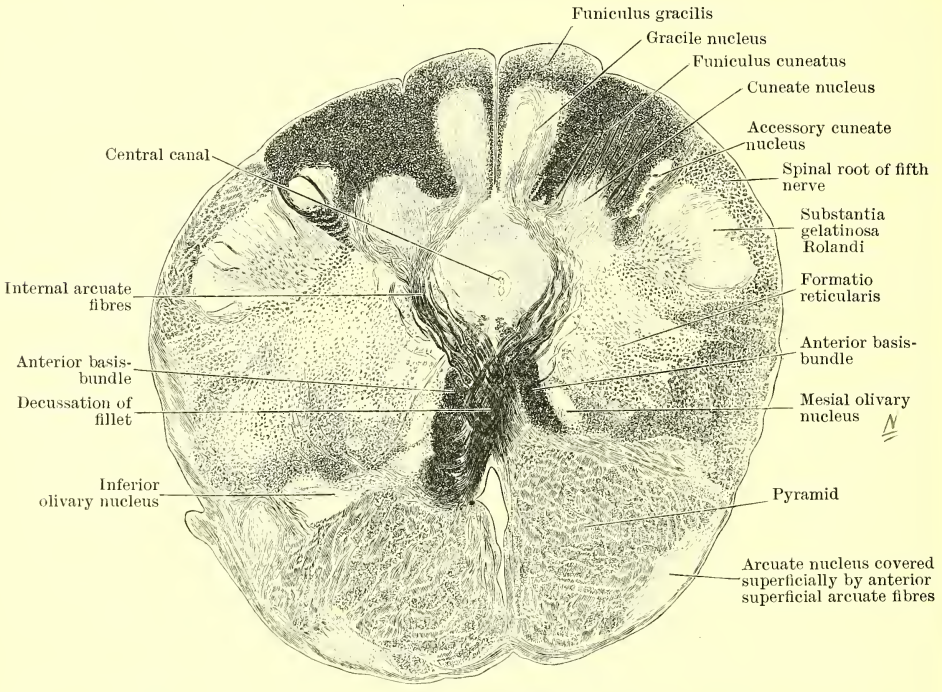


FIG. 394.—SECTION THROUGH THE CLOSED PART OF HUMAN MEDULLA IMMEDIATELY ABOVE THE DECUSSATION OF THE PYRAMIDS (Weigert-Pal Specimen).

gradually infiltrates the entire strand. At first it is not directly connected with the gray matter which surrounds the central canal; but as it is traced upwards it increases in bulk, absorbs more of the strand in which it lies, and such a connexion becomes established (Figs. 393 and 394).

The **cuneate nucleus**, from the first, is a direct offshoot from that part of the base of the posterior horn of gray matter which is preserved as a portion of the central gray mass. In transverse section it is seen to invade the funiculus cuneatus upon its deep aspect, and it gradually grows backwards into its substance. It presents a very different appearance from the gracile nucleus, because throughout its whole length the gray nucleus and the fibres of the strand are separated from each other by a sharp line of demarcation. A second and much smaller mass of gray matter appears in the funiculus cuneatus, superficial to the main nucleus, soon after the region of the decussation of the pyramids is left. This is termed the **accessory** or the **external cuneate nucleus** (Fig. 394).

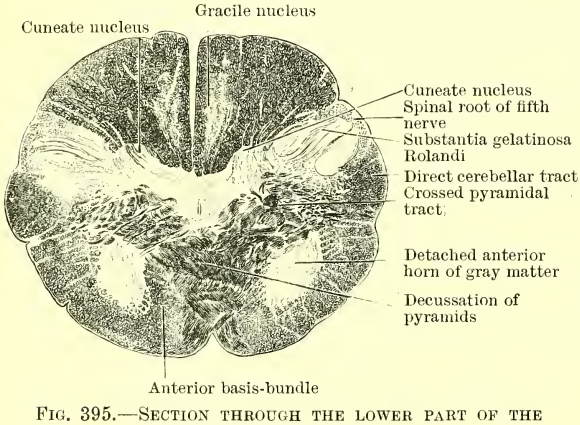


FIG. 395.—SECTION THROUGH THE LOWER PART OF THE MEDULLA OF THE ORANG.

Gradually the fibres of the gracile and cuneate strands become absorbed in these nuclei. As the gray masses gain in size a corresponding diminution in the number of fibres composing the corresponding tracts is observed, until, at the level of the clava and cuneate tubercles, it is seen that these eminences are composed almost

entirely of the gray nuclei, covered by a thin skin of the few remaining fibres of the two strands involved. It would appear that no fibres belonging to the funiculus gracilis and funiculus cuneatus get beyond these nuclei. They all end in fine terminal ramifications around the cells of the nuclei. In the case of the funiculus cuneatus the bundles of fibres, as they pass from the surface into the subjacent gray nucleus, are very distinctly seen in transverse sections through the medulla.

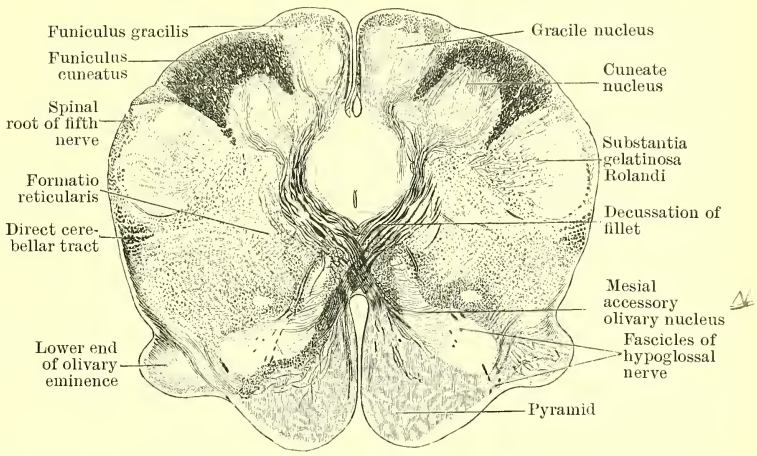


FIG. 396.—TRANSVERSE SECTION THROUGH THE CLOSED PART OF A FŒTAL MEDULLA, IMMEDIATELY ABOVE THE DECUSSATION OF THE PYRAMIDS.

Treated by Weigert-Pal method.

When the medulla oblongata opens up into the fourth ventricle the gracile and cuneate nuclei are pushed outwards by the expanding ventricular floor, and the gracile nucleus soon comes to an end; but the cuneate nucleus extends upwards for a short distance farther, and only terminates when the restiform body begins to take definite shape on its outer aspect.

Decussation of the Fillet (decussatio lemniscorum).—Immediately above the level of the decussation of the pyramids another decussation of fibres in the median plane, and upon the dorsal aspect of the pyramids, takes place in the substance of the medulla. This is termed the **decussation of the fillet**, or the **sensory decussation**, in contradistinction to the term "motor decussation," which is sometimes applied to the decussation of the pyramids. The fibres which take part in this decussation are called **deep arcuate fibres** (fibræ arcuatæ internæ), and they are derived from the cells of the gracile and cuneate nuclei. From the deep aspects of these nuclei these fibres stream forwards and inwards towards the median raphe, forming a series of concentric curves in the substance of the medulla. They cross the mesial plane and decussate with the corresponding fibres of the opposite side, upon the dorsal aspect of the pyramids. Having thus gained the opposite side of the medulla they

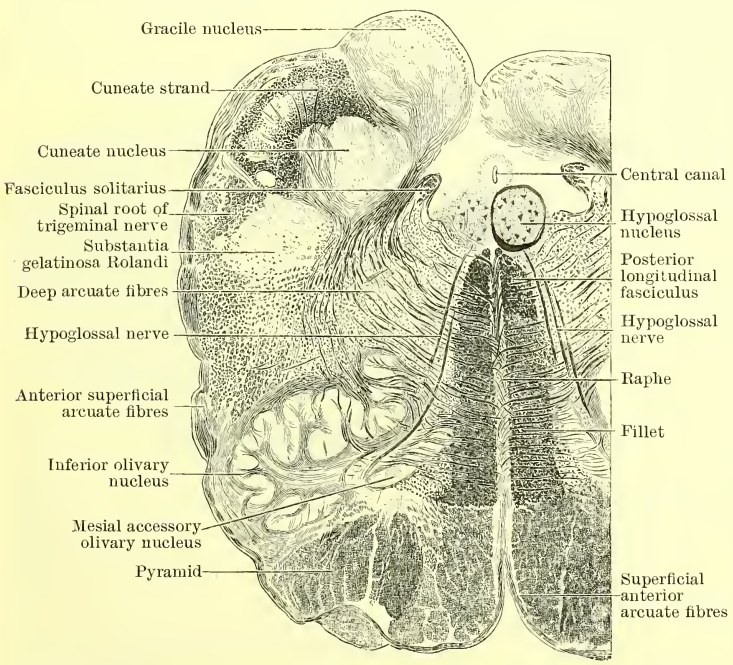


FIG. 397.—TRANSVERSE SECTION THROUGH THE HUMAN MEDULLA IN THE LOWER OLIVARY REGION.

immediately turn upwards and form a conspicuous strand of longitudinal fibres, which ascends close to the mesial plane and is separated from its fellow of the opposite side by the median raphe alone. This strand is termed the **fillet** or **lemniscus.**

As we proceed up the medulla the deep arcuate fibres which first come into sight appear as coarse bundles which curve forwards in a narrow group around the central gray matter (Figs. 394 and 396). Soon other finer bundles appear, which describe wider curves on the outer side of the coarser group until a very large part of each lateral half of the medulla is seen to be traversed by these arcuate fasciculi (Fig. 397). As they approach the mesial plane they come in contact with the remains of the anterior basis-bundle, which at this level, as already mentioned, lies upon the dorsal aspect of the pyramid, flattened up against the raphe. The deep arcuate fibres pierce the anterior basis-bundle obliquely, and in the interval between it and the corresponding strand of the opposite side they decussate in the middle line with the deep arcuate fibres of the opposite side. They then change their direction and turn upwards, and the fillet, as already stated, takes form and gradually increases in volume as it ascends. This great and important tract is thus laid down between the pyramid and the anterior basis-bundle; and the consequence of this is that the latter tract is pushed still farther backwards, and, when the fillet is fully established, it comes to lie immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 398).

It is important that we should realise at this stage the full significance of the decussation of the fillet and have a clear conception of the connexions of the fibres which take part in it. The columns of Burdach and Goll, which end in the cuneate and gracile nuclei, are derived from the posterior roots of the spinal nerves. The fillet fibres therefore carry on the continuity of the posterior columns of the cord, the gracile and cuneate nuclei, which are thrown across their path in the lower part of the medulla, merely constituting an internodal interruption. At this point the fillet strand is transferred to the opposite side of the medulla. But it will be remembered that a large proportion of the fibres of the entering posterior nerve-roots of the spinal nerves end in connexion with the cells of the posterior horn of gray matter of the cord. It must not be supposed that the path represented by these latter fibres comes to a termination thereby; from these posterior horn cells other fibres arise which cross to the opposite side of the cord in the anterior white commissure and proceed up the cord to the lateral part of the medulla. These fibres constitute the **spino-thalamic tract** already referred to. The practical bearing of this is that owing to the crossing of the fillet and lower down of the spino-thalamic tract unilateral lesions of the medulla are apt to produce complete hemi-anæsthesia; whilst unilateral lesions of the cord produce only partial hemi-anæsthesia.

NB

When the fillet is fully formed three longitudinal strands are observed traversing the medulla, close to the mesial plane. From before backwards these are: (1) the pyramid, (2) the fillet, and (3) the posterior longitudinal bundle.

The pyramid forms a massive tract in front of and quite distinct from the fillet. The fillet and the posterior longitudinal bundle are, in the first instance, not marked off from each other. They appear as a broad flattened band applied to the raphe. One edge of this band is directed backwards and reaches the gray matter on the floor of the fourth ventricle, while the other edge looks forwards, and is in contact with the pyramid. In the upper part of the medulla the fillet and the posterior longitudinal fasciculus begin to draw asunder from each other. The intermediate longitudinal fibres become reduced in number and the two strands grow denser—the one on the dorsal aspect of pyramid, and the other immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 398).

The **posterior longitudinal bundle** (fasciculus longitudinalis medialis) is thus largely formed out of fibres, which in the cord constitute the anterior basis-bundle. These fibres are thrust back by the two decussations: the first decussation pushing them behind the pyramids, and the second decussation displacing them still farther backwards to a position behind the fillet.

Olivary Nuclei.—The most conspicuous of the isolated clumps of gray matter in the medulla are the inferior olivary nucleus and the two accessory olivary nuclei. The **inferior olivary nucleus** (nucleus olivaris inferior) lies subjacent to the olivary eminence, and constitutes a very striking object in transverse sections through this region. It presents the appearance of a thick wavy or undulating line of gray matter, folded on itself, so as to enclose a space filled with white matter. It is in reality a crumpled lamina arranged in a purse-like manner, with an open

mouth or slit, which is called the **hilum** (hilum nuclei olivaris), directed towards the mesial plane. The hilum does not reach either extremity, so that in transverse

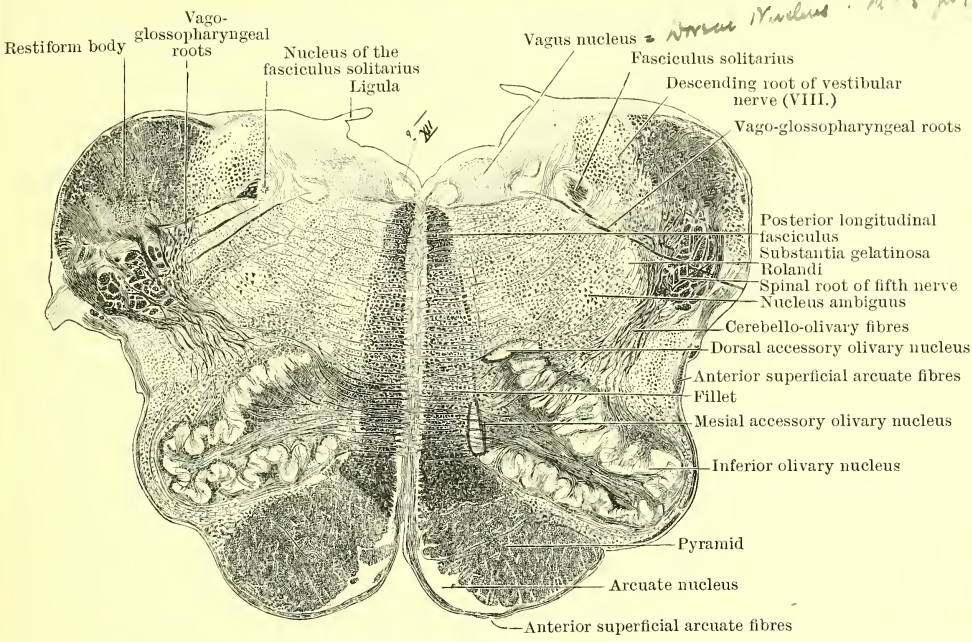


FIG. 398.—TRANSVERSE SECTION THROUGH THE MIDDLE OF THE OLIVARY REGION OF THE HUMAN MEDULLA OR BULB.

The floor of the fourth ventricle is seen, and it will be noticed that the restiform body on each side has now taken definite shape.

sections through each end of the nucleus the gray lamina is seen in the form of a completely closed capsule. Into and out of the open mouth of the olivary capsule streams a dense crowd of fibres. These constitute what is called the **olivary peduncle.**



FIG. 399.—THE INFERIOR OLIVARY NUCLEUS, as reconstructed and figured by Miss Florence R. Sabin.

View of the dorso-lateral and lateral surfaces.

The **accessory olivary nuclei** are two band-like laminæ of gray matter, which are respectively placed on the dorsal and mesial aspects of the main nucleus. In transverse section each of these nuclei presents a rod-like appearance (Fig. 398).

The **mesial accessory olivary nucleus** (nucleus olivaris accessorius mesialis) extends lower down in the medulla than the main nucleus, and it is much larger in its lower than its upper part. It begins immediately above the decussation of the pyramids, where it is seen lying on the outer side of the pyramidal tract and the anterior basis-bundle (Figs. 394 and 396). Higher up it lies across the mouth of the main nucleus and on the outer side of the fillet The **dorsal accessory olivary nucleus** (nucleus olivaris accessorius dorsalis) is placed close to the dorsal aspect of the main nucleus. The two accessory nuclei fuse together before they finally disappear.

The gray matter forming the three inferior olivary nuclei consists of a close feltwork of neuroglia in which are interspersed numerous small round cells, each of which is provided with one axon and numerous dendrites. It is traversed by fibres, some of which

pass straight through the gray lamina, whilst others end in connexion with the cells. It is only in man and the higher apes that the inferior olivary nuclei are found strongly developed. In other mammals they are much smaller. The size of the olive appears to be correlated with that of the lateral hemisphere of the cerebellum and not in any way to be dependent on the development of the cerebral hemisphere. Thus in cetacea with a very extensive cerebral cortex the inferior olivary nuclei are small (Edinger).

As the fibres of the fillet decussate and assume a longitudinal direction they come to lie between the olivary nuclei of opposite sides, and hence the term **inter-olivary stratum** (stratum interolivare lemnisci) is frequently applied to them.

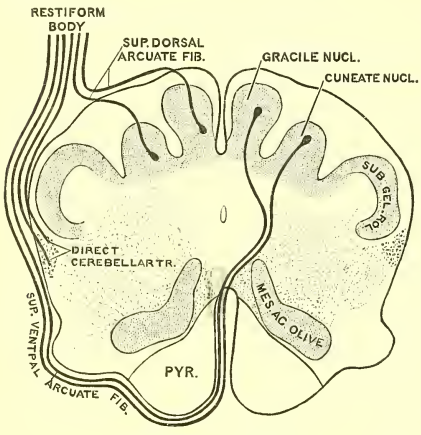


FIG. 400.—DIAGRAM,
Which shows in part the fibres which enter into the constitution of the restiform body.

Restiform Body (corpus restiforme).—The gracile and cuneate nuclei gradually give place to the restiform body in the upper part of the posterior district of the medulla. Fibres from various quarters converge to form this great strand. It first takes shape as a thin superficial layer of longitudinal fibres, which are gathered together on the outside of the cuneate nucleus; but after that nucleus has come to an end, and as the upper part of the medulla is reached, the restiform body is seen to have grown into a massive strand, which presents a kidney-shaped or oval outline on transverse section (Fig. 398), and which ultimately enters the white central core of the cerebellum as its inferior peduncle. The fibres which build up the restiform body are the following: (1) the direct cerebellar tract; (2) the posterior superficial arcuate fibres; (3) the anterior superficial arcuate fibres; and (4) cerebello-olivary fibres.

The **direct cerebellar tract** extends upwards from the lateral column of the cord. In the lateral district of the medulla it occupies a similar position; but before the olivary eminence is reached it inclines backwards, crosses the postero-lateral furrow and passes obliquely upwards into the restiform body. As its fibres diverge, backwards they pass over the tubercule of Rolando and cover up the spinal root of the trigeminal nerve and the substantia Rolandi, thus shutting them out from the surface. The fibres of the direct cerebellar tract in the first instance enter into the outer or superficial part of the restiform body.

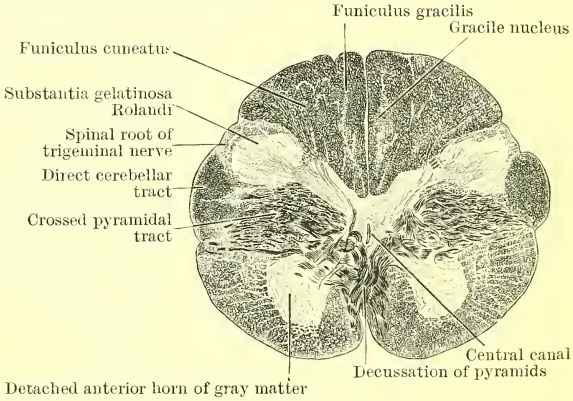


FIG. 401.—SECTION THROUGH THE JUNCTION BETWEEN THE CORD AND MEDULLA OF THE ORANG.
The direct cerebellar tract is well seen, especially on the right side.

Bruce has shown that the fibres of the direct cerebellar tract ultimately lie in the centre of the restiform body, forming as it were its central core, and that in the cerebellum they can be traced to the superior vermis.

The **posterior superficial arcuate fibres** take origin from the gracile and cuneate nuclei, and enter the superficial part of the restiform body of the same side.

The **anterior superficial arcuate fibres** proceed from the lower portions of the gracile and cuneate nuclei of the opposite side. After decussating in the middle line, it can easily be determined that all the deep arcuate fibres which arise from these nuclei do not enter the fillet. A large proportion of them gain the surface by sweeping round the inner aspect of the pyramid in the antero-mesial fissure. Many

of them likewise gain the surface by piercing the pyramid or by passing out between it and the olive. These fibres constitute the anterior superficial arcuate group, and on the surface of the medulla they sweep backwards around it, forming a thin layer over the olivary eminence and ultimately reaching the restiform body. The anterior superficial arcuate fibres, as well as the direct cerebellar tract-fibres, cover over the trigeminal spinal root, which thus comes to take up a deeper position in the substance of the medulla (Figs. 397 and 398).

Amongst the fibres which reach the surface of the medulla in this way Kölliker includes fibres from the striæ acusticæ. If this be the case, these fibres connect the cochlear nucleus with the cerebellum, the path being striæ acusticæ, superficial arcuate fibres, and restiform body (*vide* p. 522).

The fibres of the direct cerebellar tract, which come from the cells of the posterior vesicular column of the cord, and the superficial posterior arcuate fibres, which are derived from the cells of the gracile and cuneate nuclei, do not cross the mesial plane, but enter the restiform body of the same side. The anterior superficial arcuate fibres arise from the cells of the cuneate and gracile nuclei, and cross the mesial plane so as to gain the restiform body of the opposite side.

The **cerebello-olivary fibres** are only seen in the upper part of the medulla. They form the deep part of the restiform body and constitute its chief bulk. Streaming

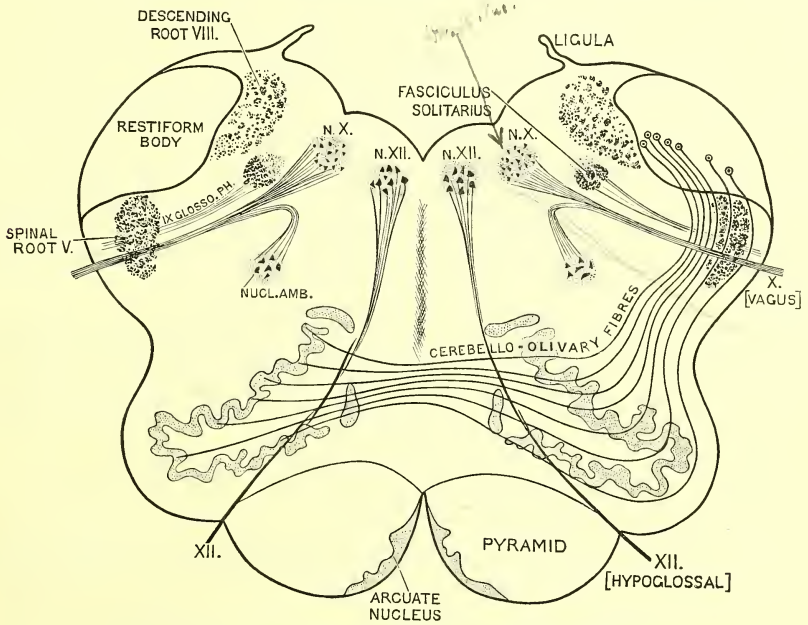


Fig. 402.—Diagram of the Cerebello-Olivary Fibres.

(This diagram has been constructed from the specimen figured on p. 495.)

N.X., Vago-glossopharyngeal nucleus. N.XII., Hypoglossal nucleus.

out from the hilum of the inferior olivary nucleus, they cross the mesial plane, and in the opposite side of the medulla they either pass through the inferior olivary nucleus of that side or sweep around it. Ultimately, on the dorsal aspect of the olivary nucleus, they are gathered together in the form of a conspicuous group of arcuate fibres, which curve backwards to take up a position in the deep part of the restiform body. In passing back, they traverse the spinal root of the trigeminal nerve and break it up into several separate bundles. The cerebello-olivary fibres thus connect the inferior olivary nucleus of one side with the opposite side of the cerebellum.

Although we have traced the cerebello-olivary tract in an upward direction from the olive to the cerebellum, and have thus inferred that it is composed of fibres which proceed from the cells of the inferior olivary nucleus of the opposite side, it is right to state that this view is not universally accepted. There are some who regard these fibres as constituting an efferent tract from the cerebellum, or, in other words, as arising in the cerebellar cortex (probably as the axons of the cells of Purkinje), and descending in the inferior cerebellar peduncle to establish connexions with the cells of the inferior olivary nucleus of the opposite side. If this view be correct, the

destination of the axons of the cells of the inferior olivary nucleus becomes a difficulty, but Kölliker considers that they enter the lateral column of the cord.

Arcuate Nucleus (nucleus arcuatus).—Immediately above the decussation of the pyramids, a small flattened mass of gray matter, covered by superficial arcuate fibres, makes its appearance on the ventral or superficial aspect of the pyramid (Fig. 393). At a higher level, when the open part of the medulla is reached, this gray mass shifts its position and comes to lie upon the mesial aspect of the pyramid, and thus constitutes the immediate boundary of the antero-median fissure (Fig. 398). From its intimate connexion with the anterior superficial arcuate fibres, as they sweep out from the antero-median fissure, it receives the name of the **arcuate nucleus.**

The nerve-cells which lie in its midst are smaller than those of the inferior olivary nucleus, and are fusiform in shape. It would appear that large numbers of the anterior superficial arcuate fibres end in this nucleus, whilst others take origin within it. Many of the anterior arcuate fibres, however, sweep continuously over its surface and bind it down to the pyramid. At the upper end of the medulla the arcuate nucleus increases in size, and ultimately it becomes continuous with the gray matter of the ventral part of the pons.

Formatio Reticularis.—Behind the olive and the pyramid is the formatio reticularis. In the medulla it occupies a position which, to a large extent, corresponds with that of the lateral column in the spinal cord. In transverse section it appears as an extensive area, which is divided into a lateral and a mesial field by the root fascicles of the hypoglossal nerve as they traverse the substance of the medulla to reach the surface. In the lateral portion which lies behind the olive there is a considerable quantity of gray matter, continuous with that in the cord, present in the reticular formation; it is, therefore, called the **formatio reticularis grisea.** In the mesial part which lies behind the pyramid the gray matter is extremely scanty, and the reticular matter here is termed the **formatio reticularis alba.**

In the **formatio grisea** many of the cells which are scattered thickly amongst the intersecting bundles of fibres are to be regarded as association cells. They possess short axons, which serve to bind different levels of the medulla to each other, and therefore constitute association fibres. Probably the combined and harmonious activity exhibited by the nuclei of the vagus, facial and phrenic nerves in the process of respiration, is attained through the nuclear connexions established by these fibres (Edinger). Certain compact masses of gray matter are also seen in the formatio grisea. Of these may be mentioned (*a*) the dorsal accessory olivary nucleus, which has been already described, and (*b*) the nucleus lateralis. The **nucleus lateralis** is seen in the region between the olive and the substantia gelatinosa Rolandi. In the upper part of the medulla it gradually becomes diffuse and disappears.

Except in the immediate vicinity of the raphe, the **formatio alba** may be said to be devoid of cells. The mesial accessory olive, however, forms an isolated compact mass of gray matter within its limits.

The nerve fibres which traverse the formatio reticularis run both in a transverse and a longitudinal direction. The **transverse fibres** are the deep arcuate fibres. The **longitudinal fibres** are derived from different sources in the two fields. In the formatio grisea they represent to a large extent the fibres of the lateral column of the cord, after the removal of the direct cerebellar and the crossed pyramidal tracts. They consist, therefore, of the fibres of the tract of Gowers and of fibres corresponding to the lateral basis-bundle of the cord. In the formatio alba the longitudinal fibres are the tract of the fillet and the posterior longitudinal bundle, both of which have already been sufficiently described.

Central Canal and the Gray Matter which surrounds it.—The central canal, as it proceeds upwards through the closed part of the medulla, is gradually forced to assume a more dorsal position, owing to the accumulation of fibres on its ventral aspect. First the decussation of the pyramids, and then the decussation of the fillet, both of which take place in front of the canal, tend to push it backwards; and the formation of the longitudinal strands in which these intercrossings result (viz. the pyramid and the fillet), together with the continuation upwards of the anterior basis-bundle, lead to a great increase in the amount of tissue which separates it from the anterior surface of the medulla. In the closed part of the medulla it is surrounded by a thick layer of gray matter, which is continuous with

the basal portions of the anterior and posterior horns of gray matter in the cord. This central gray matter is sharply defined on each side by the deep arcuate fibres which curve forwards and inwards around it. Finally, the central canal opens on the dorsal aspect of the medulla into the cavity of the fourth ventricle. The central mass of gray matter which surrounds the canal in the closed part of the medulla is now spread out in a thick layer on the floor of the fourth ventricle, and in such a manner that the portion which corresponds to the basal part of the anterior horn of the cord is situated close to the mesial plane, whilst the part which represents the base of the posterior horn occupies a more lateral position. This is important, because the nucleus of origin of the motor hypoglossal nerve is placed in the mesial part of the floor, whilst the nuclei of termination of the afferent fibres of the vagus, glosso-pharyngeal, and auditory nerves lie in the lateral part of the floor. The gray matter of the ventricular floor is covered by ependyma.

Three Areas of Flechsig.—In transverse sections, through the upper open part of the medulla, the root fibres of the hypoglossal and vagus nerves are seen traversing the substance of the medulla. The nucleus of origin of the hypoglossal is placed in the gray matter of the floor of the fourth ventricle close to the mesial plane; the nucleus of the vagus is situated in the gray matter of the ventricular floor immediately to the outer side of the hypoglossal nucleus. From these nuclei the root-bundles of the two nerves diverge from each other as they are traced to the surface and subdivide the substance of the medulla, as seen in transverse section, into the three areas of Flechsig, viz. an anterior, a lateral, and a posterior.

The **anterior area**, which is bounded internally by the median raphe and externally by the hypoglossal roots, presents within its limits: (*a*) the formatio alba; (*b*) the pyramid; (*c*) the fillet; (*d*) the posterior longitudinal fasciculus; (*e*) the mesial accessory olivary nucleus; (*f*) the arcuate nucleus.

The **lateral area** lies between the root fibres of the hypoglossal and those of the vagus. It contains: (*a*) the inferior olivary nucleus; (*b*) the dorsal accessory olivary nucleus; (*c*) the nucleus lateralis; (*d*) the nucleus ambiguus, or the motor nucleus of the vagus and glosso-pharyngeal nerves; (*e*) the formatio reticularis grisea.

The **posterior area** is situated behind the vagus roots, and within its limits are seen: (1) the restiform body; (2) the upper part of the cuneate nucleus; (3) to the inner side of this a crowd of transversely-cut bundles of fibres, loosely arranged and forming the descending root of the vestibular part of the auditory nerve; (4) close to these, but placed more deeply, a round, compact, and very conspicuous bundle of transversely-cut fibres, viz. the fasciculus solitarius, or descending root of the vagus and glosso-pharyngeal nerves; (5) the substantia gelatinosa Rolandi, much reduced, with the large spinal root of the trigeminal nerve close to its outer side.

INTERNAL STRUCTURE OF THE PONS VAROLII.

When transverse sections are made through the pons, it is seen to be composed of a ventral part and a dorsal or tegmental part. The **ventral part** is much the larger of the two, and, broadly speaking, it corresponds to the pyramidal portions of the medulla and the pedal portions of the two crura cerebri, which lie above it and appear to issue from it. The dorsal **tegmental part** may be regarded as the continuation upwards of the formatio reticularis grisea and the formatio reticularis alba. As these parts are traced upwards into the pons they become much modified, and new constituents are added.

Ventral Part of the Pons (pars basilaris pontis).—This constitutes the chief bulk of the pons. It is composed of: (1) transverse fibres arranged in coarse bundles; (2) longitudinal fibres, gathered together in massive bundles; and (3) a large amount of gray matter, termed the **nucleus pontis**, which fills up the interstices between the intersecting bundles of fibres.

The **longitudinal fibres**, to a large extent, consist of the same fibres which, lower down, are gathered together in the two solid pyramidal tracts of the medulla. When the pyramids are traced upwards they are seen to enter the pons in the form of two compact bundles. Soon, however, they become broken up into smaller bundles by the transverse fibres of the pons, and are spread out over a wider area. At the upper border of the pons they again come together and form two solid strands, each of which is carried into the central part of the corresponding pedal portion of the crus cerebri.

The **transverse fibres** at the lower border of the pons are placed on the superficial or ventral aspect of the pyramidal bundles. As we proceed upwards they increase in number, and many are seen breaking through the pyramids and even

passing across upon the dorsal aspect of the latter. Laterally these transverse fibres are collected together into one compact mass, which enters the white central core of the cerebellum and constitutes the **middle cerebellar peduncle.** At the mesial plane the transverse fibres of the two sides of the ventral portion of the pons intercross and form a coarse decussation.

The **gray matter** (the nucleus pontis) forms a considerable part of the bulk of the ventral portion of the pons. It is packed into the intervals between the intersecting transverse and longitudinal bundles.

There is a close analogy between the pyramidal portions of the medulla and the ventral part of the pons. In the medulla fine arcuate fibres on their way to the surface pass through the pyramids. Other superficial arcuate fibres sweep over the surface of the pyramids. These present a strong resemblance to the transverse fibres of the pons. They likewise reach the cerebellum, although by a different route, viz. the inferior cerebellar peduncle. The nucleus pontis is also represented in the pyramidal part of the medulla by the arcuate

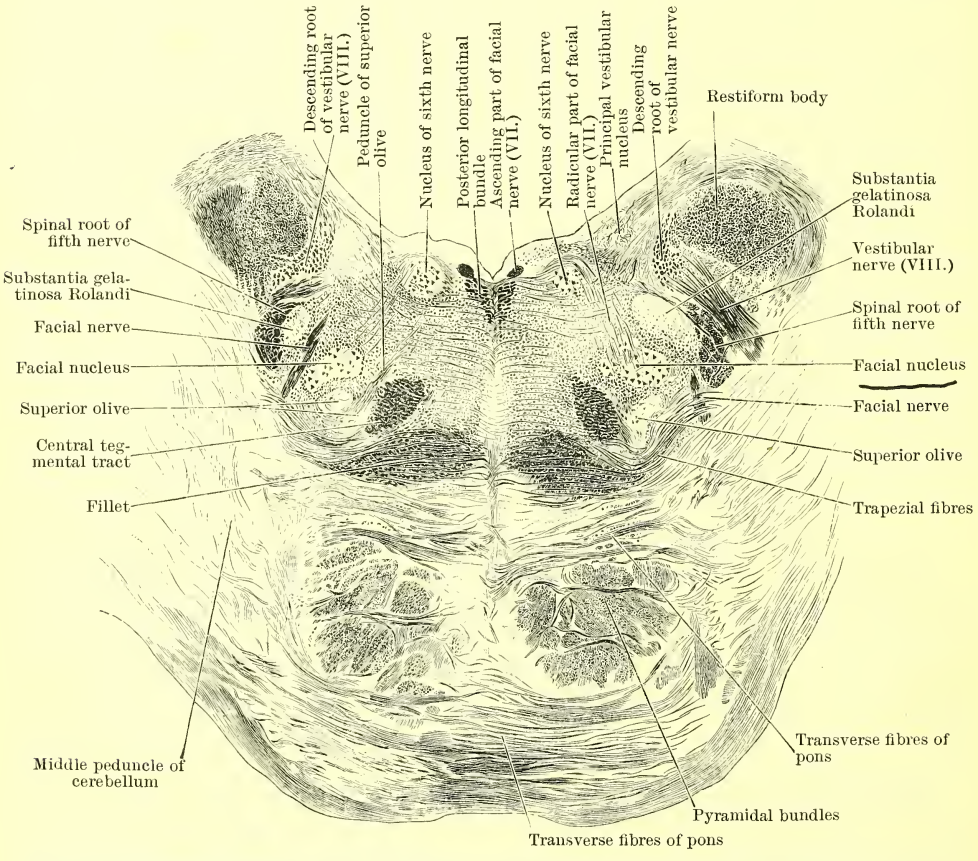


FIG. 403.—SECTION THROUGH THE LOWER PART OF THE HUMAN PONS VAROLII IMMEDIATELY ABOVE THE MEDULLA.

nuclei, which are covered over by the superficial arcuate fibres, and even tend to penetrate, to a slight extent, into the pyramidal tracts. These arcuate nuclei, as already pointed out, are continuous with the nucleus pontis.

Connexions of the Longitudinal and Transverse Fibres.—Our knowledge of the connexions of the longitudinal and transverse fibres of the ventral part of the pons is very far from being complete. When a transverse section through the upper part of the pons is compared with one close to its lower border, it becomes at once apparent that the numerous scattered bundles of longitudinal fibres which enter the ventral part of the pons from above, if brought together into one tract, would form a strand very much larger than the two pyramids which leave its lower aspect and enter the medulla. It is clear, therefore, that many of the longitudinal fibres which pass into the pons from above do not pass

out from it below into the medulla. What becomes of these fibres that are thus absorbed in the pons? It is known that the pyramidal bundles suffer a small loss by the fibres which they send to the nuclei of origin of the efferent nerves which arise within the pons (viz. the motor root of the fifth, the sixth, and seventh nerve nuclei); but this loss is, comparatively speaking, trifling. It is clear, therefore, that other longitudinal bundles enter the pons from above than those which form the pyramidal tracts. These bundles occupy a lateral and dorsal position in the ventral part of the pons, and may be termed the **cortico-pontine fibres**, seeing that they come from the cerebral cortex and end in fine ramifications around the cells of the nucleus pontis.

The transverse fibres are of two kinds, viz.: (1) those which arise in the cortex of the cerebellum; and (2) those which take origin in the nucleus pontis. The former are the axons of certain of the cells of the cortex of the cerebellum (cells of Purkinje). They come chiefly from the lateral hemisphere, but also to some extent from the median lobe of the cerebellum, and enter the pons by the middle peduncle. They end in fine ramifications around the cells of the nucleus pontis, some on the same side as the peduncle through which they reach the pons, but the majority in the gray matter of the opposite side.

The transverse fibres which arise in the pons take origin as axons of the cells of the nucleus pontis. Crossing the mesial plane, they enter the middle peduncle of the opposite side, and thus reach the cerebellar cortex, where they end in ramifications round certain of the cortical cells. The middle peduncle thus contains both efferent and afferent cerebellar fibres, and no fibres pass continuously through the pons from one middle peduncle into the other. In opposition to this view, Klimoff and others hold that the middle peduncle is composed solely of centripetal or afferent fibres, which pass from the nucleus pontis to the cerebellum. Some of these fibres are crossed and others direct.

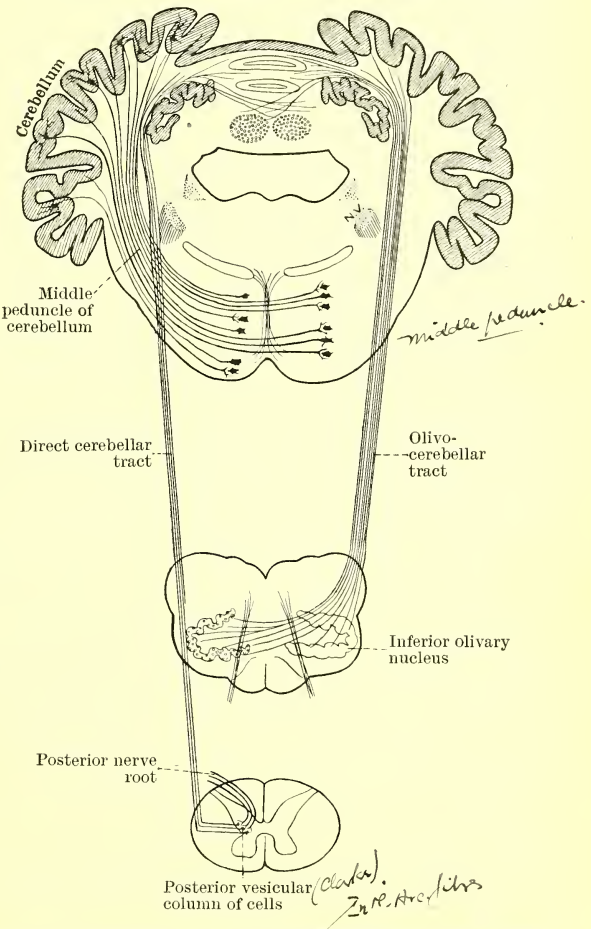


Fig. 404. — Diagram to show connexions of the Direct Cerebellar and the Olivo-Cerebellar Tracts. The connexions of the fibres of the middle peduncle of the cerebellum are likewise diagrammatically shown (from Edinger, modified).

Certain of the transverse fibres of the pons turn backwards and enter the dorsal or tegmental part of the pons, but the precise connexions of these are doubtful.

Corpus Trapezoides.—This name is applied to a group of transverse fibres which traverse the lower part of the pons (Fig. 405). They are quite distinct from those which have been just described as entering the middle peduncle of the cerebellum, and they lie in the boundary between the dorsal and ventral parts of the pons, but encroaching considerably into the ground of the former. They arise from the cells of the terminal nucleus of the cochlear division of the auditory nerve, and constitute a tract which establishes certain central connexions for that nerve. They will be more fully described when we treat of the cerebral connexions of the auditory nerve.

Dorsal or Tegmental Part of the Pons (pars dorsalis pontis).—On the dorsal surface of the tegmental part of the pons there is spread a thick layer of gray

matter, covered by ependyma, which forms the floor of the upper or pontine part of the fourth ventricle. Beneath this the mesial raphe of the medulla is continued up into the pons, so as to divide its tegmental part into two symmetrical halves.

In the *lower part of the pons,* immediately beyond the medulla, the restiform body is placed on the outer side of the tegmental part (Fig. 403). In transverse sections through the pons it appears as a large, massive oval strand of fibres which gradually inclines backwards into the cerebellum, and thus leaves the pons. Between the restiform body and the median raphe the tegmental part of the pons is composed of formatio reticularis, continuous with the same material in the medulla. Thus arcuate or transverse fibres, curving in towards the raphe, and also longitudinal fibres, are seen breaking through a mass of gray matter which occupies the interstices of the intersecting fibres. To the naked eye the formatio reticularis presents a uniform gray appearance, but its constituent parts are revealed by low powers of the microscope in properly-stained and prepared specimens. Embedded in this formatio reticularis are various clumps of compact gray matter and certain definite strands of fibres. These we shall describe as we pass from the restiform body inwards towards the median raphe.

(1) **Spinal root of the trigeminal nerve and the substantia gelatinosa Rolandi.**— Close to the inner side of the restiform body, but separated from it by the vestibular root of the auditory nerve as it proceeds backwards through the pons, is seen a large crescentic group of coarse transversely-divided bundles of fibres. This is the spinal root of the fifth nerve, and applied to its inner concave side is a small mass of gray matter, which is the direct continuation upwards of the substantia gelatinosa Rolandi.

(2) The **nucleus of the facial or seventh nerve** comes next. It is sunk deeply in the tegmental part of the pons and lies close to the transverse fibres of the corpus trapezoides. It is a conspicuous, obliquely placed, ovoid clump of gray matter. From its outer and dorsal aspect the root-fibres of the facial nerve stream backwards and inwards towards the gray matter on the floor of the fourth ventricle. Passing forwards between this nucleus and the substantia Rolandi a solid nerve-bundle may be observed. This is the facial nerve, traversing the pons towards its place of emergence from the brain.

(3) Immediately internal to the facial nucleus, but placed more deeply in the tegmental part of the pons, is the **superior olivary nucleus** (nucleus olivaris superior). It lies in a bay formed for it by the transverse fibres of the corpus trapezoides. These fibres curve round its ventral aspect, and many of them may be observed penetrating into its substance. In man it is a very small mass of gray matter, and presents little resemblance to the inferior olivary nucleus, except in the size and shape of its constituent cells. In sections through the part of the pons where it attains its greatest size, it appears in the form of two, or it may be three, small isolated masses of gray matter. It is intimately connected with the trapezial fibres, many of which end in it, whilst others take origin within it.

Upon the inner and dorsal aspect of the superior olive there is a dense group of longitudinal fibres. These constitute the **central tegmental tract**; but as precise information in regard to its connexions is still to a large extent wanting, it is not necessary to do more than indicate its position.

(4) The **posterior longitudinal bundle** and the **fillet** come next. As they proceed upwards through the tegmental part of the pons, these longitudinal tracts occupy the same relative position as in the medulla. They are placed close to the median raphe; but they have drawn further apart from each other, and their fibres are more distinctly concentrated into separate strands, with an interval of some little width between them. The **posterior longitudinal bundle** lies immediately under cover of the gray matter of the floor of the fourth ventricle. The **fillet** is placed close to the trapezial fibres, many of which traverse it as they pass towards the mesial plane.

(5) The **nucleus of the sixth nerve** also forms a conspicuous object in sections through the lower part of the pons. It is a round mass of gray matter, which is situated close to the outer side of the posterior longitudinal bundle, and immediately

under cover of the gray matter of the floor of the fourth ventricle. From its inner side numerous root-bundles of the sixth nerve pass out and proceed forwards beween the fillet and the superior olivary nucleus. They occupy in the pons, therefore, a position similar to that occupied by the hypoglossal root-fibres in the medulla.

Up to the present only the lower part of the tegmental portion of the pons has been described, *i.e.* the portion immediately adjoining the medulla. As we proceed upwards and gain a point *above the level of the trapezial fibres*, many of the structures which have attracted attention lower down gradually disappear from the formatio reticularis. The posterior longitudinal bundle, the fillet, and the spinal root of the fifth nerve, however, are still carried upwards. Further, the

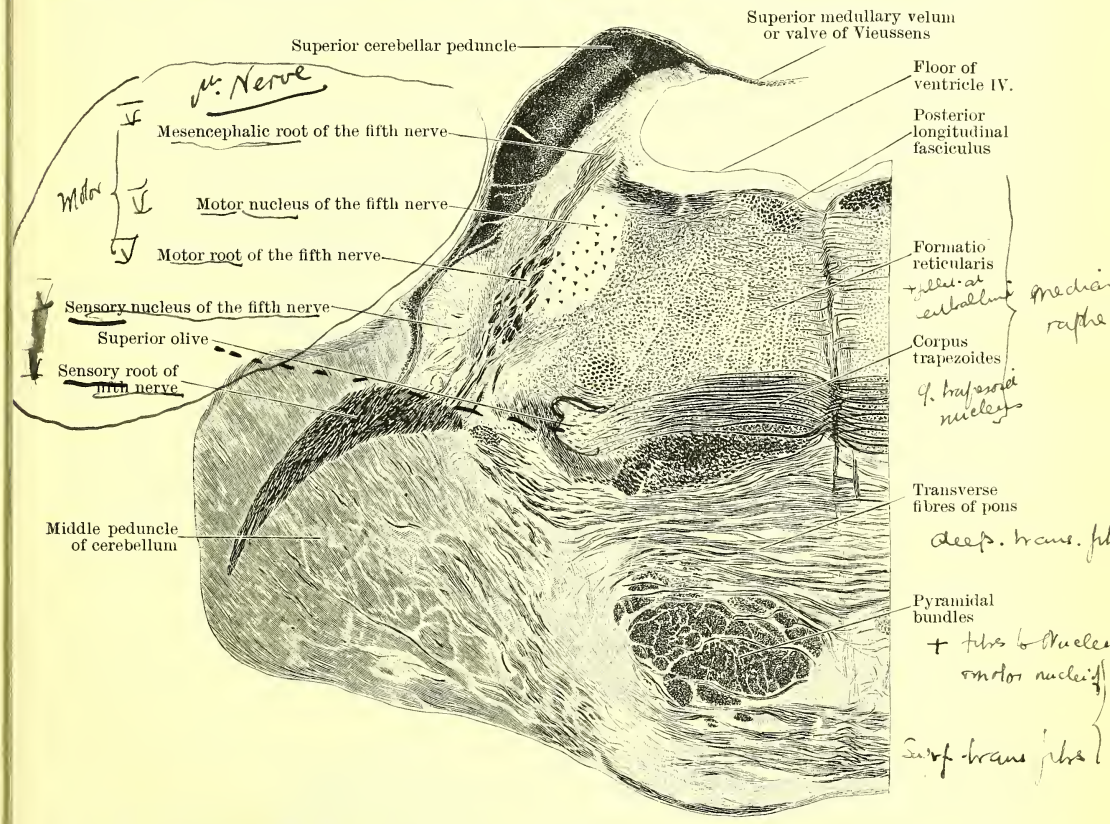


FIG. 405.—TRANSVERSE SECTION THROUGH THE PONS VAROLII AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE (Orang).

floor of the fourth ventricle becomes narrower, and other objects appear in the tegemental substance.

The **superior cerebellar peduncle** (brachium conjunctivum) is a very conspicuous object, in sections, through the middle and upper parts of the pons. In transverse section it presents a semilunar outline, and as it emerges from the cerebellum it lies immediately on the outer side of the fourth ventricle, towards which its concave aspect is turned (Fig. 405). Its dorsal border is joined with the corresponding peduncle of the opposite by the thin lamina of white matter, termed the superior medullary velum, whilst its ventral border is sunk to a small extent in the dorsal part of the pons. As it is traced upwards it sinks deeper and deeper into the pons until it becomes completely submerged, with the exception of the posterior border to which the superior velum is attached. It now lies on the outer side of the tegmental or reticular substance of the pons, and this position it maintains until the mesencephalon is reached (Fig. 406).

About *half-way up the pons* the nuclei of the trigeminal or fifth cranial nerve mark a very important stage in its tegmental portion. These nuclei are two in

number on each side, viz. a large oval terminal nucleus for certain of the sensory fibres of the nerve and a nucleus of origin equally conspicuous for certain of the motor fibres (Fig. 405). The **sensory nucleus** lies close to the outer surface of the pons, deeply sunk in its tegmental part, and in the interval between the submerged anterior border of the superior cerebellar peduncle and the ventral part of the pons. The **motor nucleus** is placed on the inner side of the sensory nucleus, but somewhat nearer the dorsal surface of the pons. At this level the spinal root of the fifth nerve disappears by joining the fibres of the sensory portion. The sensory and motor roots of the fifth nerve traverse the ventral part of the pons on their way to and from the region of the nuclei.

Above the level of the nuclei of the trigeminal nerve a new tract of fibres comes into view. This is the **mesencephalic root** of the fifth nerve, as it descends to join the emerging fibres of the motor part of the fifth nerve. It is a small bundle of nerve fibres, semilunar in cross section, which lies close to the inner side

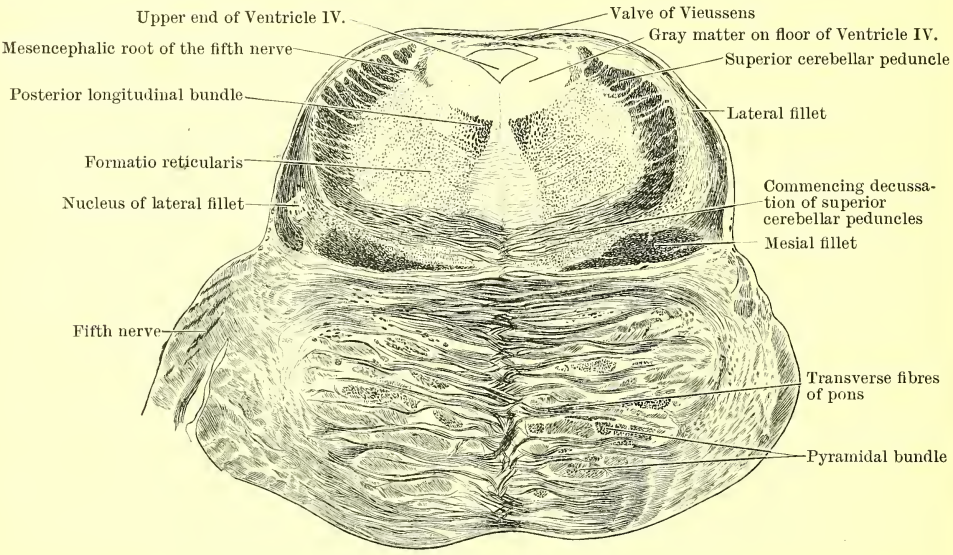


Fig. 406.—Section through the Upper Part of the Pons Varolii of the Orang, above the Level of the Trigeminal Nuclei.

of the superior cerebellar peduncle and on the outer and deep aspect of the gray matter on the floor of the fourth ventricle (Figs. 406 and 407).

On a slightly deeper plane than the mesencephalic root of the fifth nerve, between it and the posterior longitudinal bundle, and in close relation to the gray matter of the floor of the ventricle, is the collection of pigmented cells which constitutes the **substantia ferruginea.**

The **posterior longitudinal bundle,** as it is traced upwards through the tegmental part of the pons, maintains the same position throughout, and as it ascends it becomes more clearly mapped out as a definite and distinct tract. It lies close to the mesial raphe, and immediately subjacent to the gray matter of the floor of the fourth ventricle.

The **fillet** as it ascends through the tegmental part of the pons undergoes striking changes in shape. In the lower portion of the pons its fibres, which in the medulla are spread out along the side of the median raphe, are collected together in the form of a loose bundle, which occupies a wide field, somewhat triangular in shape, on either side of the median raphe and immediately behind the ventral portion of the pons. As it proceeds up, the fibres spread out laterally until a compact ribbon-like layer is formed in the interval between the tegmental and ventral portions of the pons. This constitutes what is termed the **mesial fillet** (Figs. 406 and 407).

Above the level of the trigeminal nuclei another flattened layer of fibres comes

into view to the outer side of the mesial fillet. To this the name of **lateral fillet** is given. These fibres spread outwards and backwards, and finally take up a position on the outer surface of the superior cerebellar peduncle. In the angle between the mesial and lateral fillets a little knot of compact gray matter, termed the **lateral**

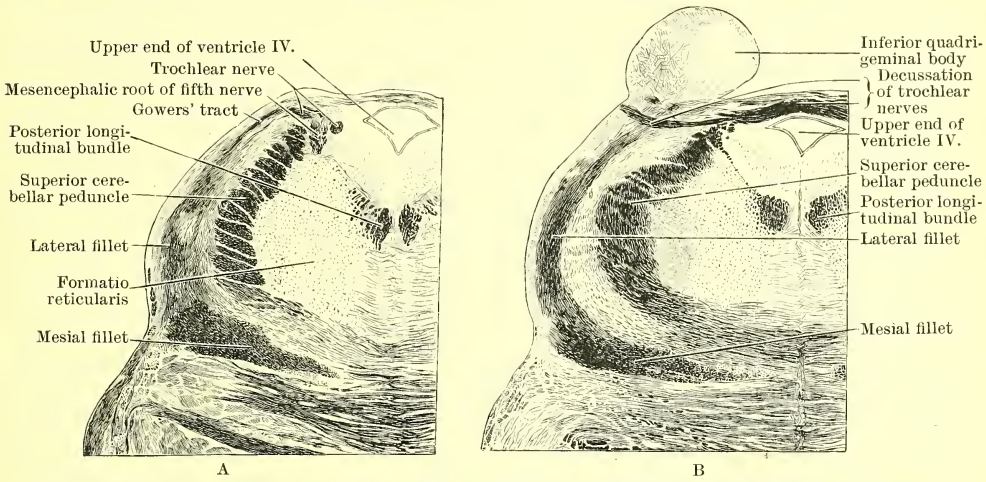


FIG. 407.—TWO SECTIONS THROUGH THE TEGMENTUM OF THE PONS AT ITS UPPER PART, CLOSE TO THE MESENCEPHALON.

A is at a slightly lower level than B.

fillet nucleus, comes into view (Fig. 406). This appears to be in more or less direct continuity with the superior olivary nucleus. Many of the fibres of the lateral fillet take origin in this nucleus. Bruce has called attention to the continuity between the superior olive and the lateral fillet nucleus in man, and the writer can confirm his statement in so far as the orang brain is concerned.

THE CEREBELLUM.

The **cerebellum** lies behind the pons Varolii and the medulla oblongata, and below the hinder portions of the cerebral hemispheres. From the latter it is

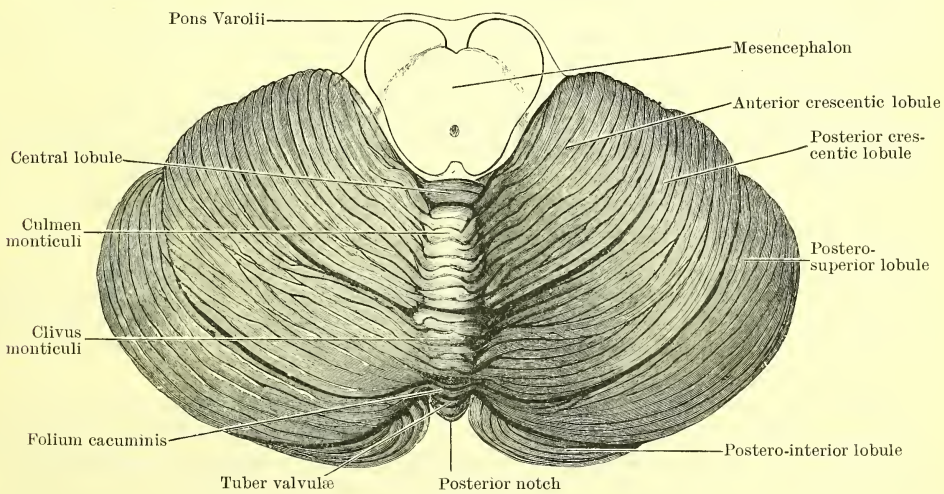


FIG. 408.—UPPER SURFACE OF THE CEREBELLUM.

separated by an intervening partition of dura mater, termed the tentorium cerebelli. It is distinguished by the numerous parallel and more or less curved sulci, which traverse its surface and give it a foliated or laminated appearance. It is composed of a cortex of gray matter (substantia corticalis) spread over its surface, with white matter in the interior, forming a central core (corpus medullare).

The cerebellum is subdivided somewhat arbitrarily into a median portion termed the **vermis**, and two much larger lateral portions, called the **lateral hemispheres** (hemisphæria cerebelli). The demarcation between these main subdivisions of the organ is not very evident from every point of view. In front, and also behind, there is a marked deficiency or notch. The **posterior notch** (incisura cerebelli posterior) is smaller and narrower than the anterior notch. It is bounded laterally by the lateral hemispheres, whilst its bottom is formed by the median lobe or vermis. It is occupied by a fold of dura mater, called the falx cerebelli. The **anterior notch** (incisura cerebelli anterior) is wide, and, when viewed from above, it is seen to be occupied by the inferior quadrigeminal bodies and by the superior peduncles of the cerebellum. As in the case of the hinder notch, its sides are formed by the lateral hemispheres and the bottom by the vermis.

On the superior surface of the cerebellum there is little distinction to be noted between the median lobe and the upper surface of each lateral hemisphere. On this aspect the median lobe receives the name of **superior vermis**, and it forms a high median elevation, from which the surface slopes gradually downwards on each side to the margin of the hemisphere. The superior vermis is highest in front, immediately behind the anterior notch, and from this it shows a somewhat sharp descent towards the posterior notch. This elevation of the superior worm is frequently called the monticulus cerebelli. The folia on the surface of the superior vermis are thicker and fewer in number than those on the upper surface of the lateral hemisphere. It is this which gives it the worm-like appearance from which it derives its name.

On the inferior surface of the cerebellum the distinction between the three main constituent parts of the organ is much better marked (Fig. 409). On this aspect the lateral hemispheres are full, prominent, and convex, and occupy the cerebellar fossæ in the floor of the cranium. They are separated by a deep mesial hollow, which is continued forwards from the posterior notch. This hollow is termed the **vallecula cerebelli**, and in its fore-part is lodged the medulla oblongata. When the medulla is raised and the lateral hemispheres are pulled apart, so as to expose the bottom of the vallecula, it will be seen that this is formed by the **vermis inferior**, or inferior aspect of the median lobe, and, further, that the latter is separated on each side from the corresponding lateral hemisphere by a distinct furrow, termed the **sulcus valleculæ**.

Sulci Cerebelli.—Certain of the fissures which traverse the surface of the cerebellum are deeper and longer than the others, and they map out districts which are termed lobes. One of the most conspicuous of these clefts is the great horizontal fissure.

The **great horizontal fissure** (sulcus horizontalis cerebelli) of the cerebellum begins in front and passes continuously round the circumference of the organ, cutting deeply into its outer and posterior margins. In front, its lips diverge to enclose the three cerebellar peduncles as they pass into the interior of the cerebellum. The great horizontal fissure divides the organ into an upper and a lower part, which may be studied separately.

The prominence which is accorded to the great horizontal fissure in descriptive anatomy is not justified by its developmental history and morphological status. It is very late in making its appearance in the fœtal cerebellum, and not infrequently the part of the fissure on the one side fails to establish a continuity across the vermis with the part of the fissure on the other side of the organ.

Lobes on the Upper Surface of the Cerebellum.—When examined from before backwards, the superior vermis presents the following subdivisions: (1) the **lingula**; (2) the **central lobule** (lobulus centralis); (3) the **culmen monticuli**; (4) the **clivus monticuli**; (5) the **folium cacuminis** (folium vermis). With the exception of the lingula, each of these is continuous on either side, with a corresponding district on the upper surface of the hemisphere, thereby forming a cerebellar lobe. Thus the central lobule is prolonged outwards on either side in the form of a small, flattened, wing-like expansion called the **ala**; the culmen constitutes the median connecting piece between the two **anterior crescentic lobules** of the hemispheres; the clivus stands in the same relation to the two **posterior crescentic lobules**; and

the folium cacuminis is the connecting band between the **postero-superior lobules** of the hemispheres.

It should be noted that this subdivision of the upper surface of the cerebellum is to some extent conventional, and in certain particulars receives little support from morphological data.

The **lingula** can only be seen when the part of the cerebellum which forms the bottom of the anterior notch is pushed backwards. It consists of four or five small flat folia continuous with the gray matter of the vermis superior, which are prolonged forwards on the upper surface of the superior medullary velum in the interval between the two superior cerebellar peduncles.

Lobus Centralis with its Alæ.—The lobulus centralis lies at the bottom of the anterior cerebellar notch, and is only seen to a very small extent on the upper surface of the organ. It is a little median mass which laterally is prolonged outwards for a short distance round the anterior notch in the form of two expansions, termed the alæ.

Lobus Culminis.—The culmen monticuli constitutes the highest part or summit of the monticulus of the vermis superior. It is bounded behind by a deep and strongly marked fissure called the **fissura prima** (Elliot Smith), and is prolonged outwards on either side into the lateral hemisphere as the **anterior crescentic lobule**. This is the most anterior subdivision on the upper surface of the hemisphere. The two anterior crescentic lobules, with the culmen monticuli, form the **lobus culminis cerebelli**.

Lobus Clivi.—The clivus monticuli lies behind the culmen, from which it is separated by the fissura prima, and it forms the sloping part or descent of the monticulus of the vermis superior. On each side it is continuous with the **posterior crescentic lobule** of the lateral hemisphere, and the three parts are included under the one name of **lobus clivi**.

The two crescentic lobules on the upper surface of the hemisphere are sometimes classed together and described as the **lobulus quadrangularis**. They are separated from each other by a lateral extension on the upper surface of the hemisphere of the fissura prima, whilst the posterior crescentic lobule is bounded behind by a curved sulcus termed by Elliot Smith the **fissura postlunata**. The union of the two postlunate furrows across the vermis separates the clivus from the folium cacuminis, but in many cases this junction fails to take place.

Lobus Cacuminis.—The folium cacuminis forms the most posterior part of the vermis superior, and when the right and left portions of the great horizontal fissure are continuous across the vermis it bounds that fissure superiorly at the posterior notch. It is a single folium, subject to considerable variation in the degree of its development, and its surface may be smooth or beset with rudimentary secondary folia. It is the median connecting link between the two **postero-superior lobules** of the hemispheres, the three parts forming the **lobus cacuminis**. As the folium cacuminis is traced outwards into the postero-superior lobule, it is found to expand greatly, and as a result of this the postero-superior lobule on each side forms an extensive foliated district bounding the great horizontal fissure above.

Lobes on the Under Surface of the Cerebellum.—The connexion between the several parts of the inferior vermis and the corresponding districts on the under surface of the two hemispheres is not so distinct as in the case of the vermis superior and the lobules on the upper surface of the hemispheres. A groove, the **sulcus valleculæ**, intervenes between the vermis inferior and the hemisphere on each side.

From behind forwards the following subdivisions of the vermis inferior may be recognised: (1) the **tuber valvulæ** (tuber vermis); (2) the **pyramid** (pyramis); (3) the **uvula**; (4) the **nodule** (nodulus).

On the under surface of the hemisphere there are four main lobules mapped out by intervening fissures. From behind forwards these are: (1) the **postero-inferior lobule**, a large subdivision which bounds the great horizontal fissure on its under aspect; (2) the **biventral lobule** (lobulus biventer) which lies in front of the postero-inferior lobule, and is partially divided into two parts by a curved fissure which traverses its surface; (3) the **tonsil** or **amygdala** (tonsilla), a small rounded lobule which bounds the fore-part of the vallecula, and is lodged in a deep concavity on

the inner aspect of the biventral lobule; (4) the **flocculus**, a minute lobule situated on the middle peduncle of the cerebellum in front of, and partially overlapped by, the anterior border of the biventral lobule.

These lobules, with the corresponding portions of the vermis inferior, constitute the lobes on the under surface of the cerebellum. Still, it should be noted that, just as in the case of the upper surface of the organ, this subdivision is to some extent artificial, and is not in every particular provided with a sound morphological basis.

Lobus Tuberis.—The tuber valvulæ, which forms the most posterior part of the vermis inferior, is composed of several transversely arranged folia which, on either side, run directly into the postero-inferior lobule. The three parts of the lobus tuberis are thus linked together.

The postero-inferior lobule, which is wider towards the vallecula than it is further out, is traversed by two or it may be three curved fissures. The most anterior of these cuts off a narrow, curved strip of cerebellar surface, which presents a more or less uniform width throughout its whole length. This is the so-called **lobulus gracilis.**

Lobus Pyramidis.—The pyramid is connected with the biventral lobule on each side by an elevated ridge which crosses the sulcus valleculæ. The term lobus pyramidis is applied to the three lobules, which are thus associated with each other.

The pyramid is separated from the tuber valvulæ by a deep furrow which has been termed by Elliot Smith the **suprapyramidal fissure.** It is in a measure continuous with the curved fissure, which on the under surface of the hemisphere intervenes between the biventral lobule and the lobulus gracilis or fore part of the postero-inferior lobule. The name applied to the latter fissure by Elliot Smith is **fissura parapyramidalis.**

Lobus Uvulæ.—The uvula is a triangular elevation of the vermis inferior. It lies between the two tonsils, and is connected with each of these by a low-lying

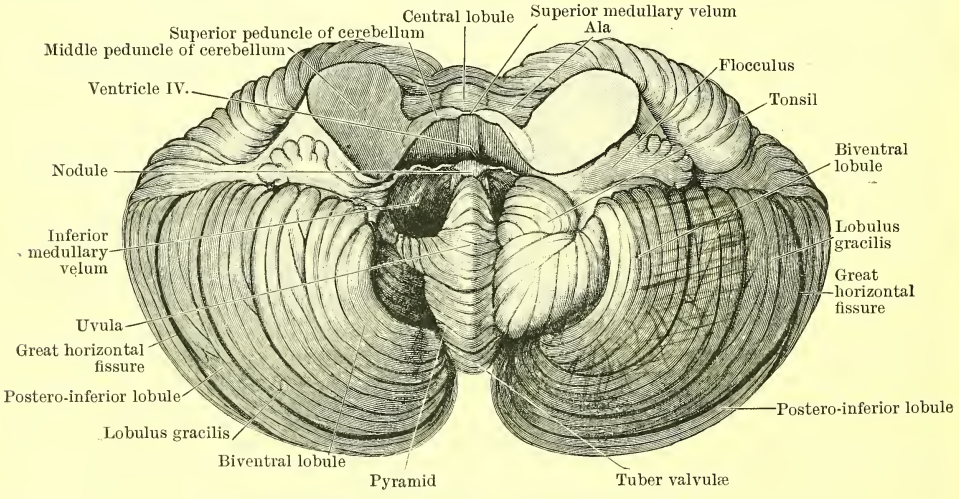


FIG. 409.—LOWER SURFACE OF THE CEREBELLUM.

The tonsil on the right side has been removed so as to display more fully the inferior medullary velum and the furrowed band.

band-like ridge of gray matter scored by a few shallow furrows, and in consequence termed the **furrowed band.** The two tonsils and the uvula form the lobus uvulæ.

Between the pyramid and the uvula there is a deep cleft which may be termed the **infra-pyramidal fissure** (the fissura secunda of Elliot Smith). This is more or less directly connected with the **retrotonsillar fissure** which curves round the tonsil. The large size of the tonsil is characteristic of the brain of man and the anthropoid apes.

Lobus Noduli.—The lobus noduli comprises the nodule and the flocculus of each side, with a delicate connecting lamina of white matter termed the **inferior medullary velum.**

The cleft between the nodule and the uvula is termed the **postnodular fissure** (Elliot Smith); that between the flocculus and the biventral lobule is called the **floccular fissure.**

The flocculus will usually be observed to be partially divided into two pieces. The smaller hinder portion, which, as a rule, is completely overlapped by the overhanging edge of the biventral lobule, is the **paraflocculus.** This assumes very large proportions in certain of the lower mammals.

Arrangement of the Gray and White Matter of the Cerebellum.—The white matter of the cerebellum forms a solid compact mass in the interior, and over this is spread a continuous and uniform layer of gray matter. In each lateral hemisphere the white central core is more bulky than in the median lobe or worm, in which the central white matter is reduced to a relatively thin bridge thrown across between the two lateral hemispheres. The white matter in the interior of the median lobe or worm is termed the **corpus trapezoides.** When sagittal sections are made through the cerebellum, the gray matter on the surface stands out clearly from the white matter in the interior. Further, from all parts of the surface of

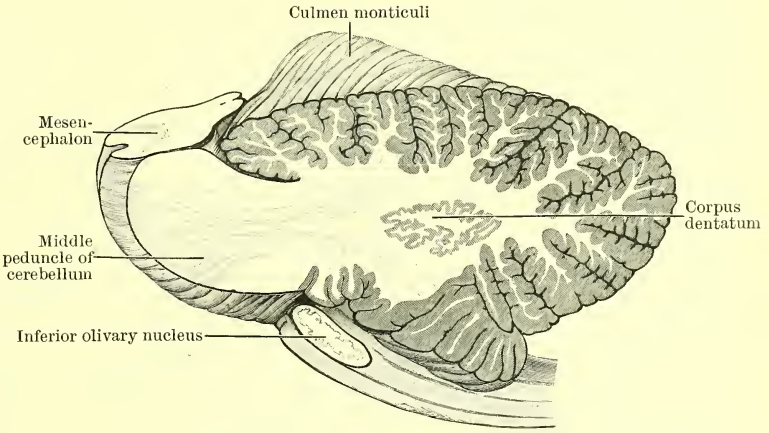


FIG. 410.—SAGITTAL SECTION THROUGH THE LEFT LATERAL HEMISPHERE OF THE CEREBELLUM,

Showing the "arbor vitæ" and the corpus dentatum.

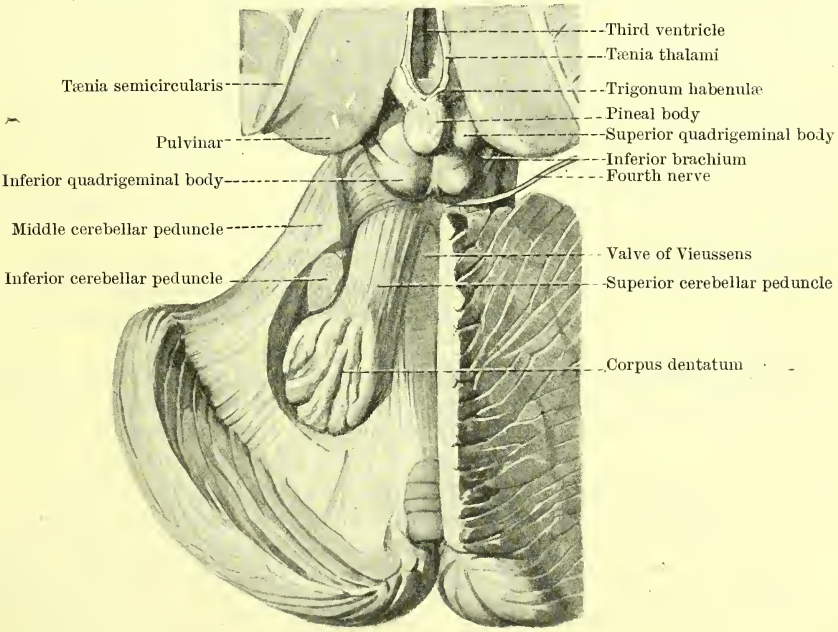


FIG. 411.—From a dissection by Dr. Edward B. Jamieson in the Anatomical Department of the University of Edinburgh. The corpus dentatum is displayed from above and the superior cerebellar peduncle has been traced from it to the mesencephalon.

the central core stout stems of white matter are seen projecting into the lobes of the cerebellum. From the sides of these white stems secondary branches proceed

at various angles, and from these again tertiary branches are given off. Over the various lamellæ of white matter thus formed the gray cortex is spread, and the fissures on the surface show a corresponding arrangement, dividing up the organ into lobes, lobules, and folia. When the cerebellum is divided at right angles to the general direction of its fissures and folia, a highly arborescent appearance is thus presented by the cut surface. To this the term **arbor vitæ cerebelli** is applied.

Corpus Dentatum and other Gray Nuclei in the White Matter of the Cerebellum.—Embedded in the midst of the mass of white matter which forms the central core of each lateral hemisphere there is an isolated nucleus of gray matter, which presents a strong resemblance to the inferior olivary nucleus of the medulla. It is called the **corpus dentatum** (nucleus dentatus), and it consists of a corrugated or plicated lamina of gray matter, which is folded on itself so as to enclose, in a flask-like manner, a portion of the central white matter (Figs. 410 and 411). This gray capsule is not completely closed. It presents an open mouth, termed the hilum, which is directed inwards and upwards, and out of this stream the great majority of the fibres of the superior cerebellar peduncle.

Three small additional masses of gray matter are also present on either side of the mesial plane in the central white matter of the cerebellum. These are termed the nucleus emboliformis, the nucleus globosus, and the nucleus fastigii. The **nucleus emboliformis** or **embolus** is a small lamina of gray matter which lies immediately internal to the hilum of the corpus dentatum, being thus related to it somewhat in the same manner that the mesial accessory olivary nucleus is related to the main inferior olivary nucleus. The **nucleus globosus** lies internal to the embolus and on a somewhat deeper horizontal plane. The **nucleus fastigii** or **roof nucleus** is placed in the white substance of the worm (corpus trapezoides) close to the mesial plane and its fellow of the opposite side. It is, therefore, situated on the mesial aspect of the nucleus globosus.

Although isolated from the gray matter of the surface, these small nuclei and the corpus dentatum are connected at certain points with each other. The corpus dentatum and the embolus present a structure very similar to that of the inferior olivary nucleus. In the nucleus globosus and the nucleus fastigii the cells are somewhat larger in size.

Cerebellar Peduncles.—These are three in number on each side, viz. the middle, the inferior, and the superior (Fig. 391, p. 487). The fibres of which they are composed all enter or emerge from the white medullary centre of the cerebellum.

The **middle peduncle** is much the largest of the three, and has already been described on pp. 486 and 501. It is formed by the transverse fibres of the pons, and it enters the cerebellar hemisphere on the outer aspect of the other two peduncles. The lips of the anterior part of the great horizontal fissure are separated widely from each other to give it admission (Fig. 409). Within the cerebellar hemisphere its fibres are distributed in two great bundles. Of these, one, composed of the upper transverse fibres of the pons, radiates out in the lower part of the hemisphere; whilst the other, consisting of the lower transverse fibres of the pons, spreads out in the upper part of the hemisphere.

The **inferior peduncle** is simply the restiform body of the medulla. After leaving the medulla it ascends for a short distance on the dorsal surface of the pons and then turns sharply backwards, to enter the cerebellum between the other two peduncles.

The **superior peduncle**, as it issues from the cerebellum, lies close to the inner side of the middle peduncle (Fig. 409). Its further course upwards on the dorsum of the pons to the inferior quadrigeminal body has been previously described (pp. 486 and 503).

Connexions established by the Peduncular Fibres.—The fibres of the **middle peduncle** are both afferent and efferent. The connexions which they establish in the pons are described on p. 501. The efferent fibres arise from cells in the gray cortex of the lateral hemisphere (also probably to some small extent in the cortex of the vermis), and end in connexion with the cells of the nucleus pontis, and likewise in the tegmental part of the pons. The afferent fibres, arising in the pons, end in the gray cortex of the lateral hemisphere of the cerebellum, and perhaps also in the cortex of the worm.

The **inferior peduncle** is also composed of afferent and efferent fibres (see p. 496); only the more important connexions which these establish in the cerebellum can be touched on here. The principal afferent strand is the *direct cerebellar tract*. The fibres of this strand end in the cortex of the superior worm on both sides of the mesial plane, but chiefly on the opposite side. The *cerebello-olivary fibres* are also probably afferent. It

appears that they end in connexion with cells in the cortex of both the worm and hemisphere, and also cells in the nucleus dentatus. The numerous *arcuate fibres* which enter the inferior peduncle establish connexions with cells in the cortex of the lateral hemisphere and of the worm.

The **superior peduncle** is an efferent tract. The majority of its fibres come from the cells of the nucleus dentatus, whilst a small proportion appear to come from the cerebellar cortex. According to Risien Russell, the fibres which form the dorsal edge of the band come from the opposite side of the cerebellum and cross the mesial plane to join the peduncle.

Our knowledge of the connexions of the peduncles of the cerebellum has been greatly extended by Ferrier and Aldren Turner; and the account which is given above, and also at p. 501, is largely derived from their memoir on this subject.

Commissural and Association Fibres.—In addition to those fibres of the white medullary centre which belong to the system of peduncles, there are others which have exclusively cerebellar connexions. Thus the various folia are bound together by numerous **association fibres**, which pass from one folium into another around the bottom of the intervening fissure. Tracts of transversely-directed **commissural fibres** cross the mesial plane in the white centre of the vermis, connecting corresponding parts of opposite sides. These, in some measure, are analogous to the corpus callosum of the cerebrum. The **roof nuclei** are also closely bound by connecting fibres with the cortex.

Medullary Vela.—The medullary vela are closely associated with the cerebellar peduncles. They consist of two thin laminæ of white matter, which are projected out from the white central core of the cerebellum.

The **superior medullary velum** is described on p. 486. Laterally, it is continuous with the dorsal edges of the superior cerebellar peduncles; whilst, inferiorly, it is prolonged downwards and backwards under the lingula and the central lobule of the superior worm, to become continuous with the central white matter or corpus trapezoides of the worm.

The **inferior medullary velum** is more complicated in its connexions. It presents much the same relations to the nodule of the inferior vermiform process that the superior velum presents to the lingula of the superior vermiform process. It is a wide thin lamina of white matter—so thin that it is translucent—which is prolonged out from the white centre of the cerebellum above the nodule. From the nodule it stretches outwards to the flocculus on each side, thereby bringing these three small portions of the cerebellum into association with each other (Fig. 409). Where it issues from the white matter of the cerebellum it is in contact with the superior medullary velum, but, as the two laminæ are traced forwards, they diverge from each other. The superior velum is carried upwards between the two superior cerebellar peduncles, whilst the inferior medullary velum is curved forwards and then downwards round the nodule, and ends at a variable point in a free, slightly thickened, crescentic edge. The cavity of the fourth ventricle is carried backwards into the cerebellum between the two vela, which thus form a peaked and tent-like root for it.

Relation of the Tract of Gowers to the Superior Medullary Velum.—The ascending tract of Gowers has been noticed in connexion with the lateral column of the cord (p. 469). The fibres which compose it are carried upwards through the formatio reticularis grisea of the medulla and the corresponding part of the tegmental portion of the pons. In this part of its course the fibres are scattered and do not form a compact strand. Reaching the upper end of the pons the tract turns backwards, enters the superior medullary velum, and proceeds downwards in it into the cerebellum.

Roof of the Fourth Ventricle.—In its upper part the roof of the fourth ventricle is formed by the superior medullary velum as it stretches across between the two superior cerebellar peduncles, and also, to some extent, by the approximation of these peduncles themselves as they approach the mesencephalon.

In its lower part the roof of the ventricle is exceedingly thin and is not all formed of nervous matter. The inferior medullary velum enters into its formation, and, where this fails, the epithelial lining of the cavity, supported by pia mater, is carried downwards towards the lower boundaries of the floor of the ventricle. At the lowest part of the calamus scriptorius, and also along each lateral boundary of

the floor, a thin lamina of white matter is carried for a short distance over the epithelial roof. The small semilunar lamina which stretches across between the lower parts of the two clavæ at the calamus scriptorius and overhangs the opening

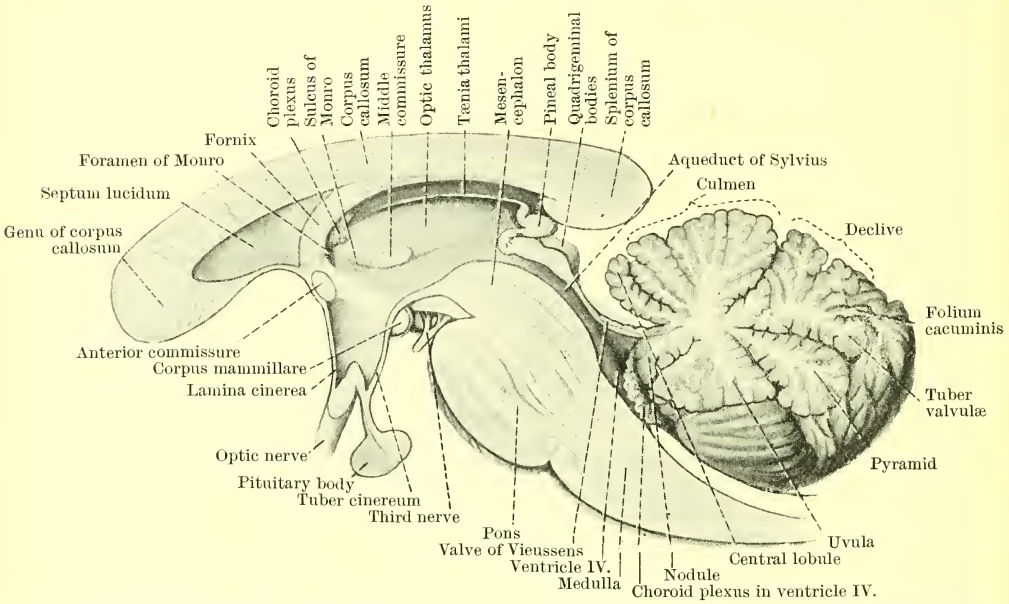


FIG. 412.—MESIAL SECTION THROUGH THE CORPUS CALLOSUM, THE MESENCEPHALON, THE PONS, MEDULLA, AND CEREBELLUM.

Showing the third and fourth ventricles joined by the aqueduct of Sylvius.

of the central canal is termed the **obex** (Fig. 391, p. 487). The lamina in connexion with the lateral boundary of the ventricular floor is more extensive, and is called the **ligula** (Figs. 388 and 390). It begins on the clava and passes upwards over the cuneate tubercle to the restiform body. On the outer surface of the restiform body it turns outwards so as to bound the lateral recess of the ventricle below, and in some cases it may be seen to become continuous around the extremity of the lateral recess with the inferior medullary velum.

A short distance above the calamus scriptorius there is, in the mesial plane, an opening in the epithelial and pial roof of the ventricle, by which the cavity of the ventricle communicates with the subarachnoid space. This opening is termed the **foramen of Majendie**. There is also an aperture of a similar nature in the epithelial and pial roof at the extremity of each lateral recess.

Two **choroid plexuses**, or highly vascular infoldings of the pia mater, invaginate the lower part of the roof of the fourth ventricle. These are placed one on either side of the mesial plane, and, although they appear to lie within the cavity, they are in reality excluded from it by the epithelial lining of the ventricle, which covers over and is adapted to every sinuosity on their surface.

Two lateral offshoots from these longitudinal choroid plexuses proceed outwards, and protrude in a similar manner into the lateral recesses.

MINUTE STRUCTURE OF A CEREBELLAR FOLIUM.

A cerebellar folium is composed of a central core of white matter, covered by a layer of gray matter. The gray cortex is arranged in two very evident layers, viz. a superficial **molecular layer** and a subjacent rust-coloured **granular layer.** Between these strata a single layer of large cells, termed the **cells of Purkinje,** are disposed in the form of a very nearly continuous sheet. The cells of Purkinje constitute the most characteristic, and probably the most essential, constituents of the cerebellar cortex.

The **cells of Purkinje** are most numerous on the summit of the folium. At the bottom of the sulci which intervene between the folia they become fewer in number, and, therefore, looser in their arrangement. Each consists of a large flask-shaped or pyriform

cell body, the narrow end of which projects into the molecular layer, whilst the thicker, deeper end rests on the granular layer. From the latter arises a **single axon**, which passes into the granular layer and presents the peculiarity of almost immediately assuming its medullary sheath. From this axon a few collateral branches soon arise, which, taking a recurrent course, enter the molecular layer, to end in connexion with certain of the adjoining cells of Purkinje. They would seem to have the function of binding together adjacent cells, and thus enabling them to carry on their operations in harmony with each other.

The **dendritic processes** spring from the narrow end of the cell either in the form of one or perhaps two stout stalks. These ascend into the molecular layer, branching and rebranching until an aborescent arrangement of extraordinary richness and extent results. The dendritic branches extend throughout the entire thickness of the molecular layer, and the branching takes place in one plane only, viz. in a plane which is transverse to the long axis of the folium. Consequently, it is only when transverse sections are made through a folium that the full dendritic effect is obtained; in sections made parallel to the long axis of the folium the cells are seen in profile, and are observed to occupy quite a narrow area (Fig. 414). The branching of the dendrites of a cell of Purkinje may, therefore, be compared to that which takes place in the case of a fruit-tree which is trained against a wall.



Fig. 413.—Transverse Section through a Cerebellar Folium (after Kölliker).

Treated by the Golgi method.

P. Axon of cell of Purkinje.
F. Moss fibres.
K and K¹. Fibres from white core of folium ending in molecular layer in connexion with the dendrites of the cells of Purkinje.
M. Small cell of the molecular layer.
GR. Granule cell.
GR¹. Axons of granule cells in molecular layer cut transversely.
M¹. Basket-cells.
ZK. Basket-work around the cells of Purkinje.
GL. Neuroglial cell.
N. Axon of an association cell.

In the **molecular layer** the cells are not particularly numerous, and of these the most characteristic are the **basket-cells** which lie in the deeper part of the layer. In addition to numerous dendrites the basket-cell gives off an axon which runs transversely, as regards the long axis of the folium, between the planes of adjacent dendritic arborisations of the cells of Purkinje. At first very fine these axons gradually become coarse and thick, and at intervals they give off collaterals which run towards the bodies of the cells of Purkinje. Reaching these, they break up into an enormous number of fine terminal branches, which enclose the cells of Purkinje, as well as the short non-medullated portions of their axons, in a close basket-work of fine filaments.

The **granular layer** is, for the most part, composed of large numbers of small granule-like bodies closely packed together. Each of these possesses a somewhat large nucleus, with a very small amount of surrounding protoplasm. From the cell body three or four, or perhaps five, dendrites and one axon proceed. The **dendrites** are short and radiate out from different aspects of the cell body. They end in tufts of claw-like twigs, which either embrace or are otherwise in contact with neighbouring granule cells. The whole multitude of granule cells, therefore, are brought into intimate connexion with each other. The **axon** passes into the molecular layer, in which it ends at a varying

distance from the surface by dividing into two branches. These diverge so sharply from each other that they almost form a right angle with the parent stem, and they run parallel to the long axis of the folium, threading their way between the branches of the various dendritic planes of the cells of Purkinje and entering into contact association with them. When the great number of granule cells is borne in mind, and the fact that each sends an axon into the molecular layer, the important part which these fibres, with their longitudinal branches, take in building up the molecular layer will be understood. They are found pervading its entire thickness—from the surface down to the bodies of the cells of Purkinje.

Near the cells of Purkinje a few scattered cells are seen in the granular layer of a different kind. These are much larger than the ordinary granule cells, and are probably of the nature of association cells. They are stellate in form, and have numerous long branching dendrites and an axon which divides up in the granular layer to a singular extent.

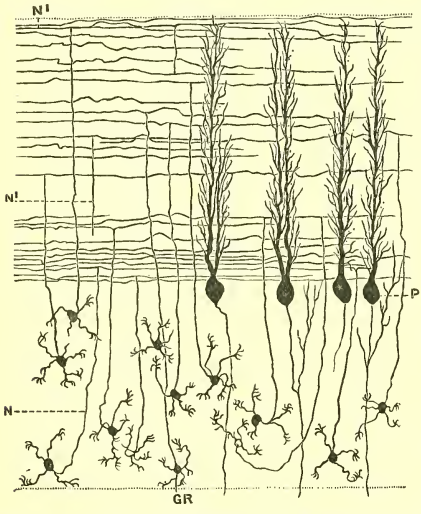


Fig. 414.—Section through the Molecular and Granular Layers in the Long Axis of a Cerebellar Folium (after Kölliker).

Treated by the Golgi method.

P. Cell of Purkinje.
GR. Granule cells.
N. Axon of a granule cell.
N¹. Axons of granule cells in molecular layer.

The **white centre** of the folium becomes thinner as it approaches the summit. This is due to the fibres which compose it gradually entering the gray matter on the surface. These fibres are of three kinds, viz.: (1) axons of the cells of Purkinje; (2) fibres which apparently end in the granular layer; and (3) fibres which end in the molecular layer.

The **axons of the cells of Purkinje** are medullated fibres which, entering the white centre of the folium, form a not inconsiderable part of it.

The fibres which end in the granular layer are called **moss-fibres.** This name is applied to them because, in the granular layer, they present at certain points moss-like thickenings, from which short rough twigs proceed.

The fibres which proceed into the molecular layer give off few or perhaps no branches as they traverse the granular layer. In the deeper part of the molecular layer they break up into varicose branches, which twine around the primary and secondary stems of the Purkinje dendrites.

Entering into the constitution of the **molecular layer** are the following elements: (1) dendrites of the cells of Purkinje; (2) basket-cells and somewhat smaller cells nearer the surface; (3) axons of the granule cells, with their longitudinally arranged branches; (4) the terminations of certain fibres from the white core of the folium, which end in contact with the Purkinje dendrites.

In the **granular layer** are found: (1) granule cells; (2) larger stellate association cells; (3) axons of the cells of Purkinje; (4) moss-fibres; (5) fibres traversing this layer, to end in the molecular layer.

THE DEEP CONNEXIONS OF THE CRANIAL NERVES ATTACHED TO THE MEDULLA AND PONS.

There are twelve pairs of cranial nerves, of which the lower eight are attached to the medulla and pons Varolii. From above downwards these are named the fifth or trigeminal, the sixth or abducent, the seventh or facial, the eighth or auditory, the ninth or glossopharyngeal, the tenth or vagus, the eleventh or spinal accessory, and the twelfth or hypoglossal. The hypoglossal, the spinal accessory, the greater part of the facial, the abducent, and the motor root of the trigeminal are efferent nerves; the auditory, the pars intermedia of the facial, and the sensory root of the trigeminal are purely afferent nerves; whilst the vagus and the glossopharyngeal are composed of both efferent and afferent fibres. In all cases afferent fibres arise from ganglionic cells placed outside the brain and penetrate the brain-stem, to end in connexion with the cells of certain **nuclei of termination.** Efferent

fibres, on the other hand, take origin within the brain as the axons of cells which are grouped together in certain places in the form of **nuclei of origin**.

Nuclei of Origin, or Motor Nuclei.—In the spinal cord the nuclei of origin are represented by elongated columns of cells which run more or less continuously in the anterior horn of gray matter of successive cord-segments, and from these the series of efferent anterior nerve-roots take origin. In the medulla and pons the nuclei of origin, or, in other words, the motor nuclei of the individual nerves become, for the most part, discontinuous, and are represented by certain isolated clumps of compact gray matter, in which are placed the clusters of cells from which the fibres of the efferent nerves arise. The nucleus ambiguus, however, which consists of a column of cells from which root fibres of the medullary part of the spinal accessory, of the vagus, and possibly also of the glossopharyngeal are derived, is an exception to this rule. At the decussation of the pyramids, the anterior horn of gray matter of the cord is broken up by the intercrossing bundles into a detached head and a basal part which remains in relation with the ventro-lateral aspect of the central canal. Certain of the efferent or motor nuclei of the medulla and pons lie in the line of the basal portion of the ventral horn of gray matter of the spinal cord, and thus close to the mesial plane. These are termed **mesial nuclei of origin**, and are met with at different levels in the brain-stem. This group comprises the hypoglossal nucleus, the dorsal motor nucleus of the vago-glossopharyngeal nerve, the abducent nucleus (and, in the mesencephalon, the trochlear nucleus and the oculo-motor nucleus). Other motor nuclei of origin are present in the form of isolated clumps or columns of gray matter, which lie at different levels in the medulla and pons in the line of the detached head of the anterior horn of gray matter. They are the nucleus ambiguus of the spinal accessory, the vagus and glossopharyngeal, the facial nucleus, and the nucleus of the motor root of the trigeminal nerve. From their position in the tegmental substance of the medulla and pons they constitute a group to which the name of **lateral motor nuclei** is applied.

The different nuclei of origin of the efferent fibres which belong to the various cranial nerves, both mesial and lateral, are connected with the motor area of the cerebral cortex by fibres from the pyramidal tract, which enter the nuclei and end in connexion with their cells.

Nuclei of Termination.—In the brain the nuclei of termination are likewise discontinuous, and are represented by more or less isolated clusters or columns of cells. Unlike the motor nuclei, however, these nuclei show no regular or definite position within the medulla and pons. Some are found in the gray matter which surrounds the central canal, and in its continuation upwards as the gray matter in the floor of the fourth ventricle; others are placed in the tegmental substance; whilst two actually lie on the surface of the brain-stem, viz. the lateral and ventral nuclei of the cochlear or outer division of the auditory nerve.

The axons of the cells of the nuclei of termination enter the reticular formation of the tegmental substance as arcuate fibres, and, crossing the mesial plane, are carried upwards in the tegmental substance of the opposite side to establish direct connexions with the optic thalamus and indirect connexions with the cerebral cortex.

Hypoglossal Nerve (nervus hypoglossus).—The nucleus of origin of the hypoglossal nerve, the motor nerve of the tongue, lies in the substance of the medulla oblongata. It is composed of several groups of large multipolar cells, which closely resemble the cells in the ventral horn of gray matter in the spinal cord, and is pervaded by an intricate network of fine fibrils. In form it is elongated and rod-like, and in length it is somewhere about 18 mm. It extends from a point immediately above the decussation of the pyramids up to the level of the striæ acusticæ. The lower portion of the nucleus is thus placed in the closed part of the medulla (Fig. 397, p. 493), whilst its upper part is situated in the open part of the medulla (Fig 402, p. 497). The former lies in that part of the central gray matter which is continuous with the basal part of the ventral horn of gray matter of the cord. It is thus placed on the ventral and lateral aspect of the central canal, close to the mesial plane and the corresponding nucleus of the opposite side. The upper part of the nucleus occupies a position in the gray matter on the floor of

the fourth ventricle, subjacent to the inner part of the surface area, which has been described under the name of the trigonum hypoglossi. Within the nucleus the axons of the cells arrange themselves in converging bundles of fine fibres, which come together and leave the ventral aspect of the nucleus as the fasciculi of the nerve. The nerve bundles thus formed traverse the entire antero-posterior thickness of the medulla between the formatio reticularis grisea and the formatio reticularis alba, and emerge on the surface in linear order at the bottom of the furrow between the olivary eminence and the pyramid. In the substance of the medulla the root-bundles of the hypoglossal pass between the main inferior olivary nucleus and the mesial accessory olivary nucleus, and many of them on their way to the surface pierce the ventral lamina of the main olivary nucleus.

No decussation between the nerves of opposite sides takes place in the medulla, but commissural fibres pass between the two nuclei (Kölliker). Further, numerous fibres from the opposite pyramidal tract enter the nucleus and end in connexion with its cells. The nucleus is thus brought into connexion with the motor area of the opposite side of the cerebral cortex.

Spinal Accessory Nerve (nervus accessorius).—The spinal accessory is likewise a motor nerve, and it is generally described as consisting of a spinal and a medullary or accessory part.

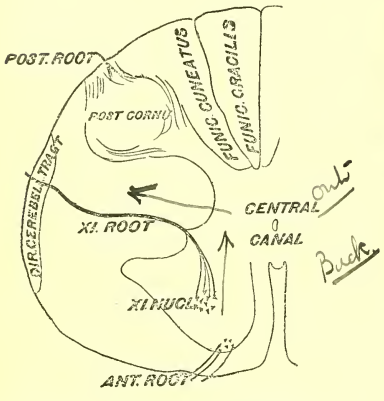


Fig. 415.—Diagram of the Spinal Origin of the Spinal Accessory Nerve (after Bruce).

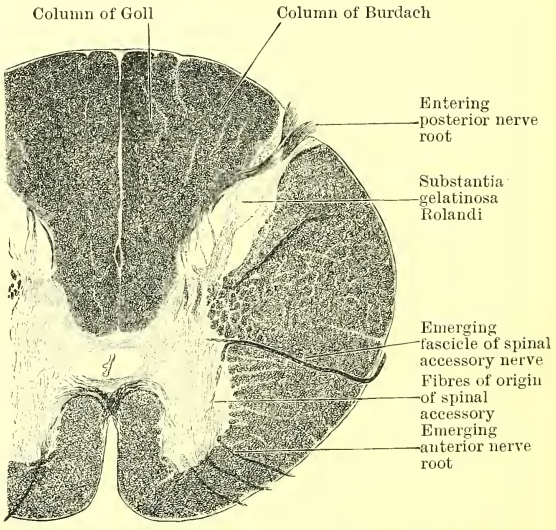


Fig. 416.—Section through the Upper Part of the Cervical Region of the Cord (Orang),
Showing the origin of the spinal part of the spinal accessory nerve.

The **spinal part** of the nerve emerges by a series of roots which issue from the surface of the lateral column of the upper part of the cord as low down as the fifth cervical nerve. These take origin in a column of cells situated in the anterior horn of gray matter of the cord close to its lateral margin, and immediately behind the nerve-cells which give rise to the fibres of the anterior roots of the upper five cervical nerves. The cells of the accessory nucleus are large, multipolar, and in every respect similar to the motor cells of the spinal nerves. The axons from these cells leave the dorsal aspect of the nucleus in converging groups to form the root-bundles of the nerve. These, in the first place, proceed straight backwards in the anterior horn of gray matter. Reaching the bay between the two horns of gray matter, they turn sharply outwards into the white matter and traverse the lateral column to gain their points of exit from the cord. At the decussation of the pyramids, root-bundles, which join the spinal accessory nerve, are seen to proceed from the detached head of the anterior horn of gray matter.

The **medullary part** of the spinal accessory nerve has its nucleus of origin in the medulla; and its root-bundles, as they proceed outwards from this, can be distin-

guished by the fact that they pursue a course on the ventral side of the spinal root of the trigeminal nerve, whereas the vagus roots, with which they are apt to be confused, pass through or lie on the dorsal aspect of the trigeminal root (Kölliker). The nucleus of origin of the medullary part of the accessory nerve is formed by the same column of cells which constitutes the **nucleus ambiguus**, and which, at a higher level, gives motor fibres to the vagus and glossopharyngeal nerves.

The part of the spinal accessory nerve which takes origin in the spinal cord supplies the sterno-mastoid and trapezius muscles. The medullary or accessory portion joins the vagus, and through the external and recurrent laryngeal nerves it supplies the muscles of the larynx. The portion of the nucleus ambiguus from which it arises has thus been termed the laryngeal nucleus (Edinger).

Collaterals and fibres of the opposite pyramidal tract end in connexion with the cells of origin of the accessory nerve, and thus bring its nucleus into connexion with the motor area of the cerebral cortex. Fibres also from the posterior roots of the spinal nerves (afferent or sensory fibres) end in the nucleus.

Vagus and Glossopharyngeal Nerves (nervus vagus, nervus glossopharyngeus).—These nerves present similar connexions with the brain, and they may therefore be studied together. The greater part of both nerves is composed of afferent fibres, which arise outside the brain-stem from ganglionic cells placed in relation to the nerve-trunks. Both nerves likewise possess motor or efferent fibres, which spring from two special nuclei of origin situated within the medulla and termed respectively the **dorsal motor nucleus** and the **nucleus ambiguus**. The afferent ganglionic fibres of the vagus and glossopharyngeal enter the brain by a series of roots which penetrate the medulla along the outer or ventral side of the restiform body. Within the medulla they separate into two sets, viz. a series of bundles (chiefly composed of vagus fibres), which end in the **dorsal nucleus of termination** of the vagus and glossopharyngeal nerves, and another series of bundles (chiefly composed of glossopharyngeal fibres), which join a conspicuous longitudinal tract of fibres called the **fasciculus solitarius**.

The **dorsal nucleus** (Figs. 398, p. 495, and 402, p. 497) of the vagus and glosso-pharyngeal nerves is mixed, and contains both motor cells which give origin to efferent fibres and cells around which afferent fibres of the vagus, and possibly also of the glossopharyngeal nerve, break up into terminal arborisations. It very nearly equals in length the nucleus of the hypoglossal nerve, with which it is closely related. Above, it reaches as high as the striæ acusticæ, whilst below its lower end falls slightly short of that of the hypoglossal nucleus. In specimens stained by the Weigert-Pal method the two nuclei offer a marked contrast. The hypoglossal nucleus presents a dark hue, owing to the enormous numbers of fine fibres which twine in and out amidst its cells; the vago-glossopharyngeal dorsal nucleus is pale from the scarcity of such fibres within it. In the closed part of the medulla the dorsal vago-glossopharyngeal nucleus lies in the central gray matter immediately behind the hypoglossal nucleus, and upon the lateral aspect of the central canal; in the open part of the medulla it lies in the gray matter of the floor of the fourth ventricle, immediately to the outer side of the hypoglossal nucleus and subjacent to the surface area termed the trigonum vagi.

The cells in the portion of the dorsal nucleus which acts as a *nucleus of termination* are spindle-shaped in form and similar to those found in the posterior horn of gray matter in the cord. In connexion with these cells, the greater number of the afferent fibres of the vagus nerve, and a small proportion of the afferent fibres of the glossopharyngeal nerve end in fine terminal arborisations. A small part of the upper portion of the nucleus may be said to belong to the glosso-pharyngeal nerve and the remainder of the nucleus to the vagus nerve.

The cells which constitute the *dorsal motor* or *efferent nucleus* as seen in transverse section appear in a more or less compact cluster, which lies immediately to the outer side of the hypoglossal nucleus. These cells, although very conspicuous, are not so large as those in the hypoglossal nucleus, nor as those in the anterior horn of gray matter of the cord; nor do they stain so deeply.

The **fasciculus solitarius** (Figs. 397, p. 493; 398, p. 495; and 402, p. 497) is a round bundle of longitudinal fibres which forms a very conspicuous object in transverse sections through the medulla. It begins at the upper limit of the medulla,

and can be traced downwards through its whole length. Its precise point of termination is not known, but it is believed that it is carried for some distance downwards into the upper part of the cord, viz. to the level of the fourth cervical nerve, according to Kölliker. The relations of the fasciculus solitarius are not the same in all parts of its course. It lies immediately to the outer side of the dorsal vago-glossopharyngeal nucleus; but whereas in the upper part of the medulla it is situated somewhat on the ventral side of that nucleus, in the lower closed part of the medulla it is placed on its dorsal aspect. Throughout its entire length it is intimately associated with a column of gelatinous gray substance which constitutes the nucleus of termination in which its fibres end. When traced from above downwards, the solitary tract is observed to become gradually smaller from the loss of fibres which it thus sustains. The great bulk of the solitary tract is formed of fibres derived from the glossopharyngeal nerve; only a few of the afferent fibres of the vagus enter it. As the fibres of the two nerves join the tract they immediately turn downwards, and at different levels come to an end in the associated gelatinous gray nucleus.

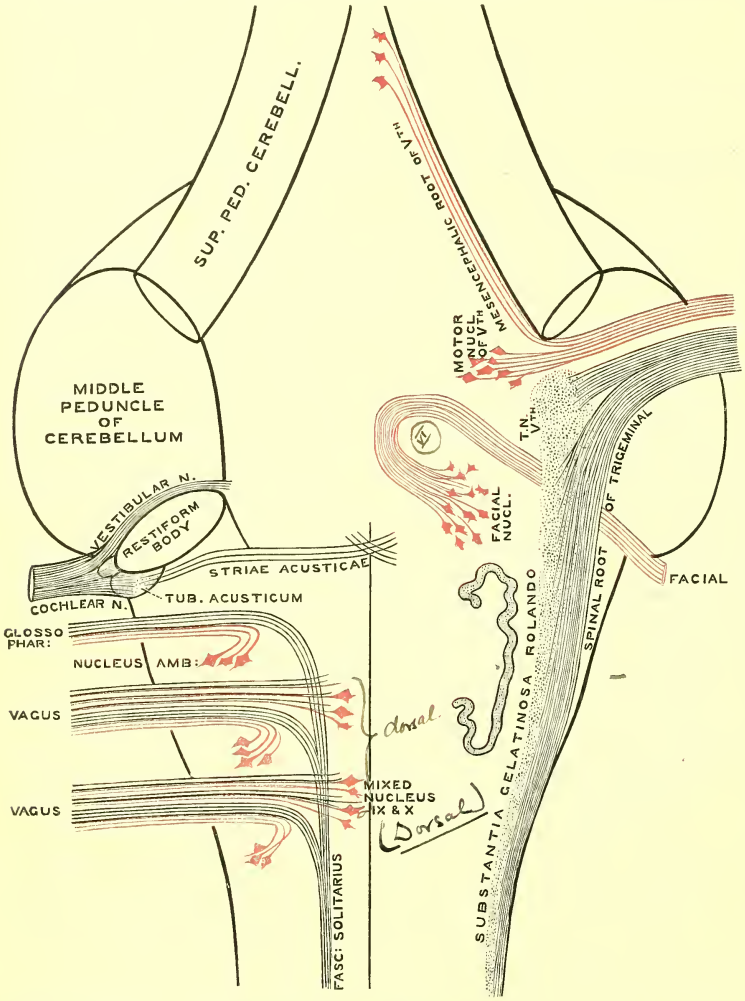


FIG. 417.—DIAGRAM, showing the brain connexions of the vagus, glossopharyngeal, auditory, facial, abducent, and trigeminal nerves.

As the root-bundles of the vagus and the glossopharyngeal nerves traverse the substance of the medulla in a backward and inward direction to reach the fasciculus solitarius and the dorsal nucleus of termination, they pass through the spinal root of the trigeminal nerve and the substantia gelatinosa Rolandi associated with it. The term **ascending root** is sometimes applied to the fasciculus solitarius; but as this conveys an altogether false conception of its character it should be discarded. The axons of the nucleus of termination and of the nucleus of the fasciculus solitarius form central connexions with other parts of the brain, but these have not as yet been completely elucidated.

The **dorsal efferent nucleus** gives off fibres which join the afferent fibres of the vago-glossopharyngeal rootlets as they traverse the medulla, and mixing with them they pass along the same path to emerge from the medulla.

The **nucleus ambiguus** (Figs. 398, p. 495, and 402, p. 497) also gives origin to

motor or efferent fibres which join the vagus and glossopharyngeal nerves. The cells which compose it are large, multipolar, and similar in every respect to the large cells in the ventral horn of gray matter of the spinal cord. These cells are arranged in a slender column which is best developed in the upper open part of the medulla. Here the nucleus can easily be detected in transverse sections as a small area of compact gray matter which lies in the formatio reticularis grisea, midway between the dorsal accessory olive and the substantia gelatinosa Rolandi. It therefore lies more deeply in the substance of the medulla than the mixed dorsal vago-glossopharyngeal nucleus. Kölliker states that it can be traced downwards as low as the level of the decussation of the fillet, and upwards as high as the place of entrance of the cochlear root of the auditory nerve. From its dorsal aspect the axons of the cells proceed, and in the first instance they pass backwards towards the floor of the fourth ventricle; then, bending suddenly outwards and forwards, they join the afferent roots of the vagus and possibly also of the glossopharyngeal nerves, and emerge from the brain in company with these.

Upon anatomical grounds it might be questioned whether the glossopharyngeal nerve contains any efferent fibres. It gives off, it is true, one motor branch, viz. to the stylo-pharyngeus muscle, but there are paths by means of which these fibres might enter the nerve other than by coming directly from the motor nuclei, which have been described in connexion with the vago-glossopharyngeal nerve-roots.

There is, further, some ground for the belief that all the fibres of the glossopharyngeal pass into the fasciculus solitarius. In a very instructive case described by Alexander Bruce in which the glossopharyngeal was destroyed in the jugular foramen by the pressure of a tumour, no degenerated fibres could be traced beyond the fasciculus solitarius.

Auditory Nerve (nervus acusticus).—This is a large nerve which joins the brain at the lower border of the pons Varolii and on the ventral aspect of the restiform body. It is an afferent nerve, and its fibres spring from bipolar ganglionic cells either within or in the immediate neighbourhood of the labyrinth or internal ear (see section dealing with the organs of sense). Reaching the brain the auditory nerve divides into two parts, viz. the nervus cochlearis and the nervus vestibularis, which present totally different connexions and apparently exercise absolutely distinct functions. In their further course these two divisions deviate from each other so as to embrace the restiform body—the vestibular part entering the pons on the inner or mesial aspect of the restiform body, whilst the cochlear part sweeps round its outer surface. Special nuclei of termination require to be studied in connexion with each part of the nerve.

The **cochlear nerve** is composed of finer fibres than the vestibular nerve, and these acquire their medullary sheaths at a later period. It is the true nerve of hearing, and its fibres end in a ganglion which lies in intimate relation to the restiform body, and which may be described as consisting of two parts. Of these one, called the **tuberculum acusticum** or the **lateral cochlear nucleus**, is a pyriform mass which is placed on the outer aspect of the restiform body—between it and the flocculus of the cerebellum. The second part, termed the **ventral cochlear nucleus**, does not extend so low down as the tuberculum acusticum. It is a wedge-shaped nuclear mass which is placed on the ventral aspect of the restiform body in the interval between the cochlear and vestibular divisions of the auditory nerve, after they have separated from each other. The fibres of the cochlear nerve enter these two ganglia and end around the cells in terminal arborisations, which are finer, closer, and more intricate than those met with in any other nerve nucleus in the brain.

The **vestibular nerve** enters the brain at a slightly higher level than the cochlear nerve and on the mesial aspect of the ventral cochlear nucleus. It forces its way backwards through the pons between the restiform body, which lies on its outer side, and the spinal root of the fifth nerve, which is placed on its inner side. Its fibres come to an end in three nuclei of termination, which are situated in the dorsal part of the pons and medulla, viz. (1) the principal nucleus or dorsal nucleus; (2) the nucleus of the descending root; and (3) the nucleus of Deiters.

The **principal nucleus** (Figs. 403, p. 500, and 418, p. 520) is a large diffuse nuclear mass, which lies in the floor of the fourth ventricle subjacent to the surface

district known as the *area acustica* (Fig. 391, p. 487). It is situated, therefore, in both the pons and the medulla to the outer side of the fovea superior and the fovea inferior. In transverse section it is prismatic in outline, and crossing the surface of its upper or pontine part immediately under the ependyma of the ventricle are the striæ acusticæ.

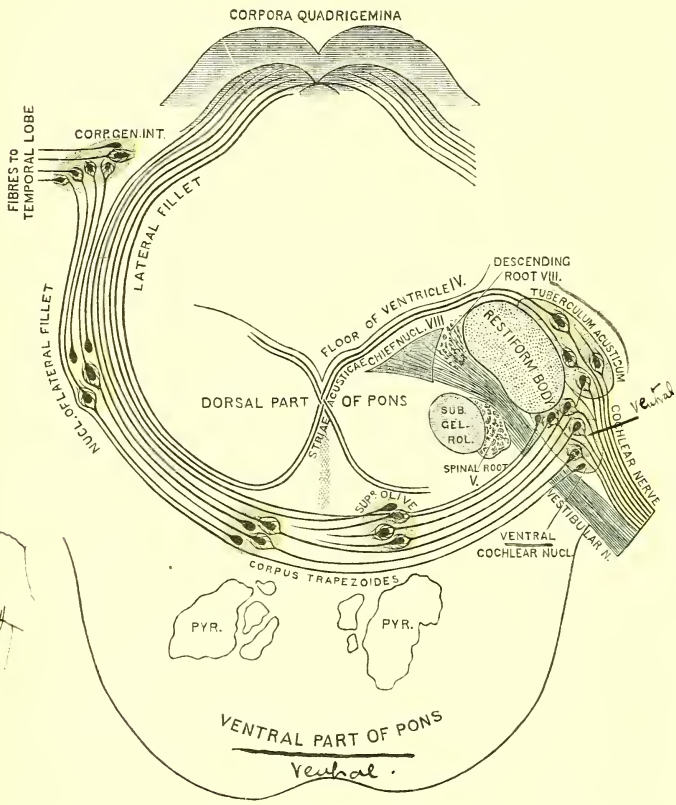


FIG. 418.—CENTRAL CONNEXIONS OF THE COCHLEAR AND VESTIBULAR DIVISIONS OF THE AUDITORY NERVE.

(Diagram founded on drawings by Edinger and Ferrier and Turner.)

When the nervus vestibularis, as it traverses the brain, reaches the inner aspect of the dorsal portion of the restiform body, a very large proportion of its fibres turn vertically downwards in separate bundles and form the descending root of the vestibular nerve (Figs. 398, p. 495; 402, p. 497; 403, p. 500; 418, p. 520). This proceeds through the lower part of the pons into the medulla, in which it may be traced as far as the level of the decussation of the fillet. Associated with the descending root there is a column of gray matter, with nerve-cells strewn sparsely throughout it. This is the **nucleus of the descending root**, and the fibres end in fine arborisations around these nerve-cells.

The fibres of the vestibular nerve likewise end in the **nucleus of Deiters.** This nucleus is composed of a number of large and conspicuous multipolar nerve-cells, which are scattered amidst the bundles of the upper part of the descending root of the vestibular nerve. As it is traced upwards into the pons the nucleus gradually inclines backwards, and finally it occupies a place in the lateral wall of the fourth ventricle. It attains its greatest development at the level of the emerging part of the facial nerve, and this upper part is sometimes termed the **nucleus of Bechterew.**

Central Connexions of the Cochlear Nerve.—The cochlear nerve is brought into connexion with the inferior quadrigeminal body, and the corpus geniculatum internum of the opposite side by the fibres of the corpus trapezoides and the lateral fillet. But this connexion is not direct; the chain is composed of several separate links or neurons superimposed one over the other.

The fibres of the cochlear nerve end in the ventral cochlear nucleus and in the tuberculum acusticum. From the cells of these nuclei two tracts arise, viz. a **ventral tract**, composed of the fibres of the corpus trapezoides, and a **dorsal tract**, which is represented by the striæ acusticæ.

The **corpus trapezoides** (Figs. 418 and 419) is formed of the axons of the cells of the ventral cochlear nucleus, as well as certain of the axons of the cells of tuberculum acusticum. In the midst of the corpus trapezoides are lodged large cells which are known as the *nucleus trapezoideus*, and these give off axons which join the strand with which they are associated. Further, the *superior olive* forms an important internode in the path of the corpus trapezoides. Many of the fibres of the corpus trapezoides end in this

internode, whilst others are added to the tract from the cells of that nuclear mass. So constituted, the trapezial fibres cross the mesial plane and decussate with the corresponding fibres of the opposite side. Reaching the opposite superior olivary nucleus a further interchange of fibres takes place, and almost immediately after this the strand turns upwards and becomes the **lateral fillet** (Figs. 405, p. 503; 406, p. 504). But still another nucleus is interposed in its path, viz. the *nucleus of the lateral fillet*. Here some fibres are dropped, whilst from the nuclear cells others are acquired, and the lateral fillet then proceeds onwards without further interruption until it reaches the inferior quadrigeminal body and the corpus geniculatum internum, in which its fibres end. It is probable, however, that some likewise extend into the superior quadrigeminal body.

But the lateral fillet also includes the fibres of the **striæ acusticæ** of the opposite side. These fibres arise from the cells of the tuberculum acusticum, and arrange themselves in the conspicuous bundles which sweep round the dorsal aspect of the restiform body and proceed inwards across the floor of the fourth ventricle, immediately beneath the ependyma (Fig. 391, p. 487). Reaching the middle line they dip forwards into the substance of the medulla, and, crossing the mesial plane, they join the lateral fillet.

It is well to remember that the connexion between the terminal cochlear nuclei and the inferior quadrigeminal body is not altogether with that of the opposite side, as the foregoing description and the diagram (Fig. 418) might lead one to infer. A few fibres pass directly to the inferior quadrigeminal body of the same side, but none to the corresponding corpus geniculatum internum: the connexion with the latter is entirely *crossed* (Ferrier and Turner).

From the corpus geniculatum internum there proceeds a tract to the gray cortex of the superior convolution of the temporal lobe. The whole nervous apparatus is thus linked on to the cerebral cortex, and the succession of neurons which build up the entire chain are therefore: (1) the bipolar cells of the ganglion spirale; (2) the neurons of the terminal cochlear nuclei; (3) the neurons of the superior olive and the nucleus of the lateral fillet; (4) the neurons of the corpus geniculatum internum.

It must be borne in mind that all the axons of the cells of the superior olive do not join the trapezoid strand. Many leave its dorsal aspect and pass backwards in a group called the **pedicle of the superior olive**, to end in the nucleus of the sixth nerve, and, through the posterior longitudinal bundle, in the nuclei of the fourth and third nerves. In this way the organ of hearing is brought into connexion with the nuclei, which preside over the movements of the eyeballs (Figs. 403, p. 500, and 420, p. 523).

Central Connexions of the Vestibular Nerve.—Although the central connexions of the vestibular nerve have been closely studied by many observers, they are still very far from being fully understood. The principal nucleus and the nucleus of Deiters both stand in intimate relation with the superior vermis of the cerebellum; and in consideration of the fact that the vestibular nerve is the nerve of equilibration, this is an important and significant circumstance. The strand which establishes this connexion has been termed by Edinger "the direct sensory cerebellar tract," and in all probability it is an efferent tract from the cerebellum. Its fibres arise to a large extent in the cerebellar **roof nuclei** of the opposite side, and, crossing the mesial plane, they sweep forwards around the outer side of the superior cerebellar peduncle as it emerges from the cerebellum to end in the nucleus of Deiters, the chief vestibular nucleus, and very possibly also in the terminal sensory nuclei of certain other cranial nerves, such as the trigeminal, vagus, and glossopharyngeal.

Until the precise nature of the nucleus of Deiters is discovered, the exact character of the central connexions of the vestibular nerve will remain more or less obscure. It cannot be regarded as a nucleus specially given over to the vestibular nerve. Composed of large cells scattered amidst the bundles of the upper part of the descending root of the vestibular nerve, it only becomes a compact nucleus above the level of that nerve, viz. at the point where the restiform body turns backwards into the cerebellum, or, in other words, at the level of the emerging facial nerve and the lower end of the abducent nucleus. Here, in the outer part of the floor of the fourth ventricle, its cells are gathered together in a crowded mass. Deiters himself considered that this nucleus should be regarded as an internode between the cerebellum and the spinal cord, and Ferrier and Turner have brought forward strong evidence in support of this view. Klimoff attaches a very high importance to the direct "sensory" tract of Edinger. From his description it would appear that he regards it as the only cerebellar efferent tract which takes a downward direction. He believes, further, that the axons of the cells of Deiters form the anterior marginal tract of Löwenthal (tractus vestibulo-spinalis of Monakow), which

descends in the antero-lateral column of the cord as far as the lumbar region. It is supposed that the fibres of this tract end in the cord in arborescent terminations around the motor cells in the ventral horn of gray matter.

From what has been said it must be apparent that the nucleus of Deiters plays a most important part in connexion with the maintenance of the equilibrium of the body and the co-ordination of its muscular movements. Thus it constitutes an internode in the path of those fibres which connect the cortex and roof nuclei of the cerebellum with the motor apparatus of the spinal cord; it receives fibres through the vestibular nerve from the labyrinth of the ear; and it sends fibres into the posterior longitudinal bundle, through which it in all probability exercises some influence over the nuclei of the ocular nerves.

Opinion is also divided as to the composition and nature of the so-called descending root of the vestibular nerve. After division of the eighth nerve, Ferrier and Turner were unable to detect any degeneration in this root, and they therefore are inclined to call in question its direct continuity with the nerve. They consider that in all probability it forms an internuncial connexion between the nucleus of Deiters and the cuneate nucleus, in which Bruce has seen its lower end to terminate.

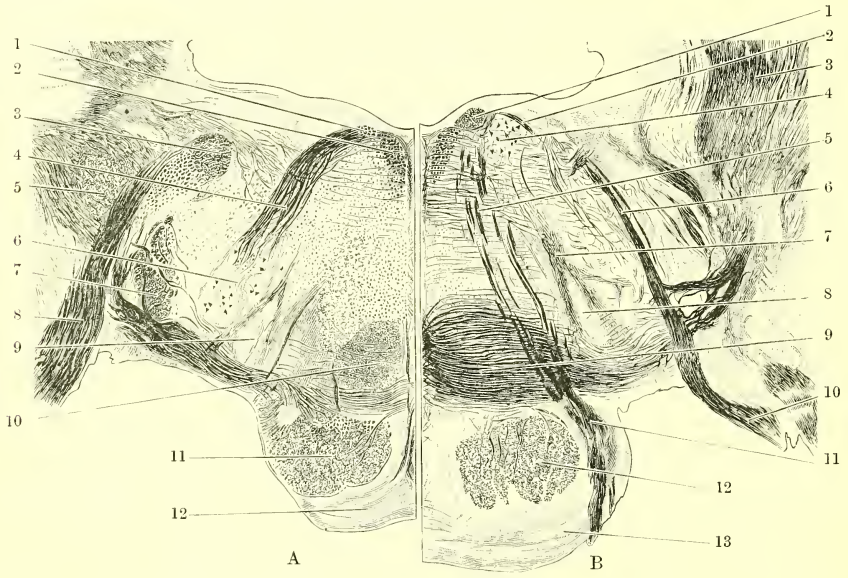


FIG. 419.—SECTION THROUGH THE PONS VAROLII OF THE ORANG,

Showing the nucleus and intrapontine course of the facial nerve. The left side of the drawing is taken from a section at a slightly lower level than the section from which the right side is taken.

A

1. Ascending part of facial nerve.
2. Posterior longitudinal bundle.
3. Descending root of eighth nerve.
4. Radicular fibres of facial nerve.
5. Restiform body.
6. Facial nucleus.
7. Spinal root of fifth nerve.
8. Vestibular nerve.
9. Superior olive.
10. Fillet.
11. Pyramidal tract.
12. Transverse fibres of pons.

B

1. Ascending part of facial nerve.
2. Emergent portion of facial nerve.
3. Restiform body.
4. Nucleus of sixth nerve.
5. Sixth Nerve.
6. Emergent part of facial nerve.
7. Peduncle of superior olive.
8. Superior olive.
9. Corpus trapezoides.
10. Facial nerve.
11. Sixth nerve.
12. Pyramidal tract.
13. Transverse fibres of pons.

Facial Nerve (nervus facialis) (Figs. 419 and 420).—The facial nerve is composed of two distinct parts, viz. a large efferent or motor portion, the **facial nerve proper**, and a small afferent sensory portion termed the **pars intermedia of Wrisberg.** The facial nerve emerges from the brain at the lower border of the pons, immediately in front and to the inner side of the auditory nerve, whilst the pars intermedia sinks into the upper part of the medulla between the facial and auditory nerves. The three nerves, therefore, lie in intimate relation with each other, where they are attached to the surface of the brain, and they pass in company into the internal auditory meatus.

The **nucleus of origin of the facial nerve** is an oval mass of gray matter, about five mm. in length, and containing numerous groups of large multipolar cells. It is sunk deeply in the dorsal or tegmental part of the lower portion of the pons Varolii, and is placed close to the inner side of the spinal root of the fifth nerve. When transverse sections are made through the brain-stem, the facial nucleus is encountered the moment the boundary line between the medulla and pons is passed, and the region immediately above the inferior olivary nucleus is reached. At first it lies so deeply in the tegmentum of the pons that it actually rests upon the dorsal aspect of the corpus trapezoides; but a little farther up the superior olive comes into view, and insinuates itself between the facial nucleus and the trapezial fibres. The upper part of the nucleus is in this way tilted somewhat backwards, and thus comes to lie on the dorsal and outer aspect of the superior olive.

The facial nucleus is situated close to the place where the nerve emerges from the brain, but the nerve does not at once pass to this point of exit. It pursues a long and devious path within the pons before it finally reaches the surface. This intrapontine part of the nerve may be divided into three parts, viz.: (1) a radicular part, (2) an ascending portion, and (3) an emergent part.

The **radicular part of the facial nerve** (Fig. 420) is composed of a large number of fine loosely-arranged bundles of fibres, which issue from the outer and dorsal aspect of the nucleus and proceed backwards and slightly inwards through the pons. Reaching the floor of the fourth ventricle they curve inwards, and the bundles which lie highest up sweep over the outer and dorsal aspect of the lower part of the nucleus of the sixth nerve. Close to the mesial plane they turn sharply upwards and are collected into a single solid nerve-bundle, which constitutes the **ascending part of the facial nerve** (Figs. 419 and 420). This proceeds vertically upwards immediately beneath the ependyma of the ventricular floor, on the dorsal aspect of the posterior longitudinal bundle, and along the inner side of the sixth or abducent nucleus for a distance of about five millimetres. Suddenly the nerve bends outwards at a right angle, and curves a second time over the dorsal aspect of the sixth or abducent nucleus. The nerve now passes straight to the place of exit from the brain, and this part of the intrapontine trunk may be termed the emergent portion (Figs. 419 and 420). The facial nerve thus forms a curved loop over the dorsal aspect of the abducent nucleus. The **emergent part** of the nerve takes an oblique course through the pons to reach the surface. It inclines outwards and downwards as it proceeds towards the ventral aspect of the pons, and on its way it passes between its own nucleus and the spinal root of the fifth nerve.

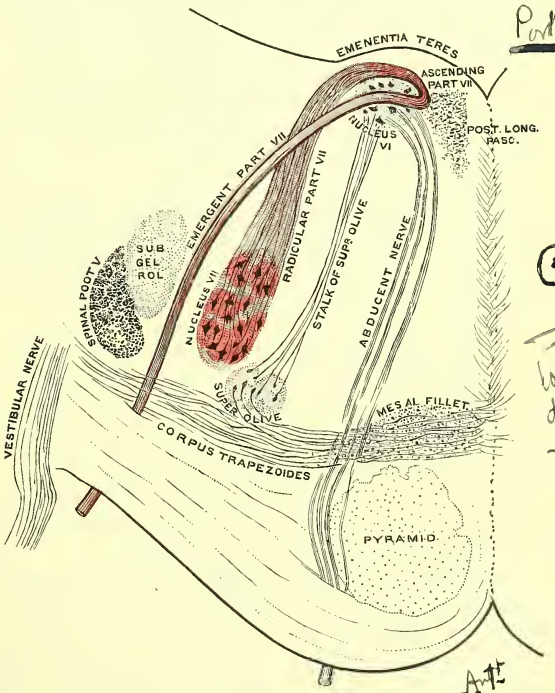


FIG. 420.—DIAGRAM OF THE INTRAPONTINE COURSE PURSUED BY THE FACIAL NERVE.

Entering the facial nucleus, and ending in fine terminal arborisations around its cells, are many fibres from the opposite pyramidal tract; fibres from the spinal root of the fifth nerve; fibres from the corpus trapezoides, etc. The nucleus is thus brought into connexion with the motor area of the cerebral cortex, with the trigeminal nerve or sensory nerve of the face, and with the auditory nerve, etc.

The fibres of the **pars intermedia of Wrisberg** arise from the cells of the geniculate ganglion of the facial nerve. These, like the cells of a spinal ganglion, are unipolar, the single process in each case dividing into a peripheral and a central branch. The group of peripheral fibres represent the chorda tympani branch of the facial nerve, whilst the central fibres form the pars intermedia. The latter penetrate the brain, and, passing either through or on the dorsal side of the spinal root of the fifth nerve, they finally reach the upper part of the column of gray matter in connexion with the fasciculus solitarius, and in this they end. The pars intermedia presents, therefore, the same terminal connexions within the brain as the glossopharyngeal nerve.

Efferent secretory fibres are also described as being present in the pars intermedia. These are said to spring from cells which constitute a *salivary nucleus* placed in the pons on the dorsal aspect of the facial nucleus.

Abducent or Sixth Nerve (nervus abducens) (Figs. 419 and 420).—This is a small motor nerve which emerges from the brain at the lower border of the pons on the outer side of the pyramid of the medulla. It is the nerve of supply to the external rectus muscle of the eyeball. Its nucleus of origin is a small spherical mass of gray matter, containing large multipolar cells, which lies in the dorsal part of the tegmental portion of the pons, close to the mesial plane and immediately subjacent to the gray matter of the floor of the fourth ventricle. Its position can be easily indicated on the ventricular floor, seeing that it is placed subjacent to the emenentia teres and immediately above the level of the striæ acusticæ. Its peculiar and intimate relation to the intrapontine portion of the facial nerve has already been indicated. It lies on the ventral aspect of, and within the concavity formed by, the two limbs of the loop of that nerve.

The axons of the multipolar cells of this nucleus emerge from the inner aspect of the nucleus in the form of several bundles, which proceed through the whole antero-posterior thickness of the pons towards the place of exit. As they pass forwards they incline downwards and slightly outwards. In the tegmental part of the pons they proceed forwards on the inner side of the superior olive, whilst in the ventral part of the pons they keep for the most part to the outer side of the pyramidal bundles, although several of the nerve fasciculi pierce these on their way to the surface.

It would appear probable that certain of the axons of the cells of the abducent nucleus enter the posterior longitudinal fasciculus and proceed upwards in it to join the third or oculomotor nerve of the opposite side. Further mention of these will be made later on. Fibres and collaterals from the pyramidal tract of the opposite side enter the nucleus, and, ending around the cells, bring the nucleus into connexion with the motor area of the cerebral cortex. The pedicle of the superior olive ends partly within the nucleus of the abducent nerve (p. 521).

Trigeminal or Fifth Nerve (nervus trigeminus).—The trigeminal nerve strikes its roots deeply into the brain and establishes a connexion with it which extends from the upper part of the mesencephalon above to the level of the second cervical nerve below. No other cranial nerve presents so extensive a connexion (Fig. 417, p. 518). It is composed of two roots—a large afferent or sensory root and a small efferent or motor root. Both roots appear close together on the surface of the pons, rather nearer its upper border than its lower border, and in the same line as the facial and auditory nerves.

The **sensory root of the fifth nerve** is composed of fibres which arise outside the brain from the cells of the Gasserian ganglion. They end within the brain in two nuclei of termination. One of these is situated in the pons and is termed the sensory nucleus of the trigeminal nerve, and the other is a long column of gray matter which is directly continuous below with the substantia gelatinosa Rolandi of the spinal cord.

The **sensory nucleus** (Fig. 421) is an oval mass of gray matter which is placed half-way up the pons in the outer part of its tegmental portion. It lies close to the outer surface of the pons and immediately subjacent to the ventral submerged margin of the superior cerebellar peduncle. It is directly continuous with the substantia gelatinosa Rolandi, and may be regarded as being merely the enlarged upper end of that column of gray matter.

The fibres of the sensory root of the fifth nerve, on reaching the sensory nucleus, divide in a manner similar to the fibres of the entering posterior roots of the spinal nerves into a system of ascending and descending branches (Fig. 417, p. 518). The ascending fibres are short, and almost immediately enter the sensory nucleus and end within it; the descending fibres turn sharply downwards and form the **spinal root** (tractus spinalis: the ascending root of many text-books). This root descends on the outer side of the column of gray matter formed by the substantia gelatinosa Rolandi, which constitutes its terminal nucleus. Fibres constantly leave it to enter the nucleus, so that the lower it gets the smaller does the spinal root become until, in the upper part of the spinal cord, about the level of the first or second spinal nerve, it disappears altogether.

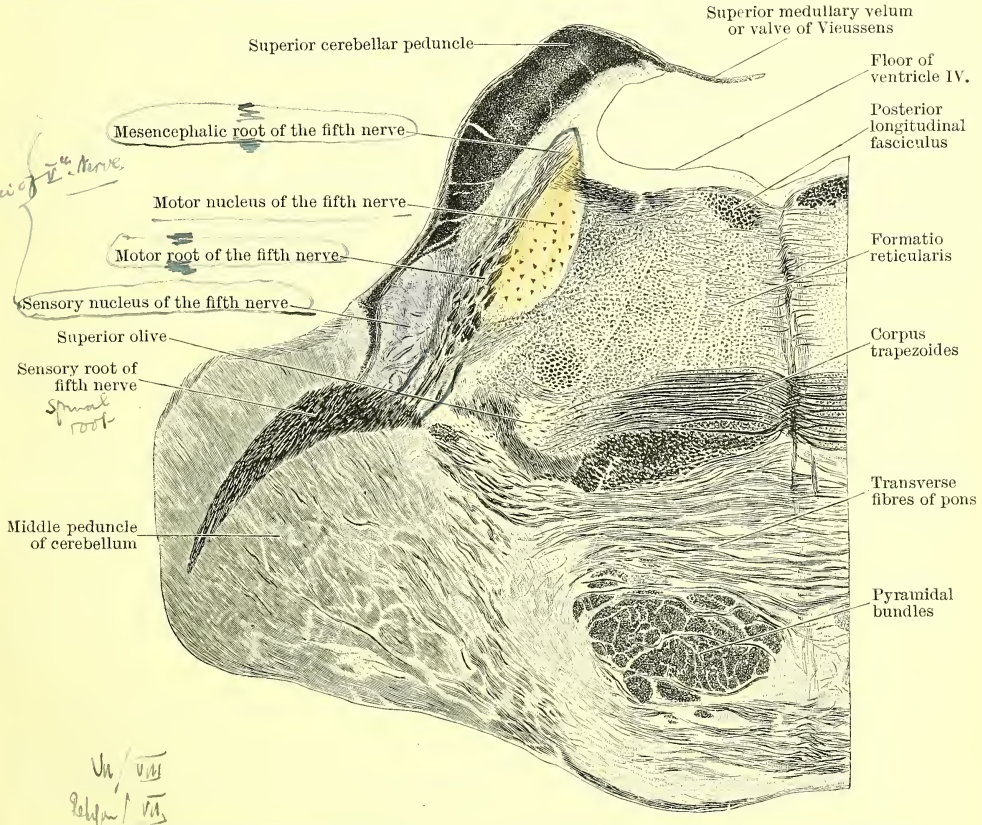


FIG. 421.—SECTION THROUGH THE PONS VAROLII OF THE ORANG, AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE.

The large spinal root of the fifth nerve is a conspicuous object in sections through the pons and medulla. In the former it traverses the tegmental part, first, between the emergent part of the facial nerve and the vestibular nerve; and then lower down, between the restiform body and the nucleus of the facial nerve (Fig. 419, A, p. 522). In cross sections it presents a well-defined semilunar or curved pyriform outline. In the upper part of the medulla it lies on the ventral aspect of the restiform body, and therefore nearer to the surface (Fig. 398, p. 495). Here it is traversed and broken up into separate bundles by the cerebello-olivary fibres and the roots of the glossopharyngeal and vagus nerves. Finally, it comes to the surface and its fibres are spread over the area on the side of the medulla known as the tubercle and funiculus of Rolando (Fig. 394, p. 492).

The small **motor part of the trigeminal nerve** is chiefly distributed to the muscles of mastication, and derives its fibres from two sources, viz. from the motor nucleus and from the mesencephalic root of the trigeminal nerve.

The **motor nucleus** (Fig. 421) lies in the lateral part of the tegmental portion of the pons, close to the inner side of the sensory terminal nucleus, but somewhat

nearer to the floor of the fourth ventricle. It is not placed in the exact line of the facial nucleus, as it is situated somewhat nearer the dorsal aspect of the pons; but, nevertheless, it may be considered as being equivalent in this region to the detached head of the anterior horn of gray matter in the lower part of the medulla. The cells of this nucleus are large and multipolar, and their axons run together to form the greater portion of the motor root of the fifth nerve.

The **mesencephalic root** takes origin in the mesencephalon from a column of large loosely-arranged cells which are placed in the extreme lateral part of the gray matter which surrounds the Sylvian aqueduct. As the lower end of this column of cells reaches the pontine part of the floor of the fourth ventricle it becomes continuous with the dark cells of the locus cœruleus. The mesencephalic root as it is traced downwards gradually gains strength by the addition of new fibres, and it assumes a crescentic form in transverse section (Figs. 430, p. 535; 432, p. 537; 407, p. 505; 406, p. 504). In the lower part of the mesencephalon it lies on the inner side of the superior cerebellar peduncle; and the fourth nerve, on its way to the surface, runs downwards in its concavity and on its mesial aspect. In the upper part of the pons, it continues its course downwards on the outer and deep aspect of the gray matter which forms the floor of the fourth ventricle, and here it stands in relation to the cells of the locus cœruleus. Finally, reaching the level of the nuclei of the trigeminal nerve, the fibres of the mesencephalic root turn forwards and join the motor part of the trigeminal nerve (Fig. 421).

S. Ramon y Cajal has shown that an intimate relationship is established between the mesencephalic nucleus and the principal motor nucleus of the trigeminal nerve. Large numbers of collaterals from the fibres of the mesencephalic root enter the latter nucleus and break up into close networks around its cells. It has been suggested that through this connexion a weak impulse proceeding from the higher nucleus may be transformed within the lower or principal nucleus into a powerful excitation.

(1) It is not known to what parts the fibres of the mesencephalic root go. Kölliker suggests that they supply the tensor veli palatini and the tensor tympani; perhaps, also, they may be distributed to the mylo-hyoid and the anterior belly of the digastric. (2) Fibres from the opposite pyramidal tract go to the motor nucleus and bring it into connexion with the motor area of the cerebral cortex. (3) By degeneration methods the root of the fifth nerve has been traced down to the level of the second cervical nerve (Ferrier and Turner). (4) The axons of the terminal nuclei emerge as arcuate fibres, and, proceeding through the raphe, assume a longitudinal course in the tegmentum of the opposite side, and thus establish connexions with parts higher up (tractus quinto-thalamicus). (5) Some of the axons of the cells of the terminal nucleus enter the motor nucleus, and thus establish a simple reflex apparatus.

The Development of the Parts derived from the Rhombencephalon.

A general sketch of the development of the medulla, pons, and cerebellum has already been given (p. 476). It is only necessary, therefore, in this section to call attention to some of the more important details connected with the process.

Medulla.—In the embryo the cervical flexure indicates in a sharp and definite manner the point of junction between the cord and the brain (Fig. 382, p. 477). In the early condition of the rhombencephalon the calamus scriptorius extends downwards to this level, so that, in the first instance, there is no part of the medulla which corresponds to the closed portion present in the adult. The lower closed part of the medulla makes its appearance at a later period, and is termed by His the **intercalated portion** (Schaltstück).

In our study of the development of that part of the neural tube which forms the spinal cord we have recognised two thick lateral walls connected in front and behind by narrow mid-ventral and mid-dorsal laminæ. The same parts are seen in the developing medulla. Owing, however, to the expansion of the cavity in this portion of the tube the mid-dorsal lamina is stretched out into an extensive and thin epithelial membrane which forms the dorsal wall or roof of the ventricle in this section of the early brain. The thick lateral walls have also fallen away from each other, and are joined in front by the narrow mid-ventral lamina. On section, therefore, the medullary part of the neural tube presents a triangular figure—the base, which is directed backwards, being formed by the thin epithelial expansion derived from the mid-dorsal lamina, the apex by the narrow mid-ventral lamina, and the sides by the thick lateral walls of the tube. Further, each lateral wall consists of an alar or dorsal and a basal or ventral lamina. This subdivision is more clearly indicated than in the cord, and on the inner surface of the lateral wall a strongly-marked longitudinal furrow marks the line of junction of the two laminæ. The histo-

logical development of these several parts of the wall of the medullary portion of the neural tube proceeds in a manner very similar to that already detailed in the case of the cord. No neuroblasts are formed in the mid-ventral and mid-dorsal laminæ; the entire neuroblastic formation is confined to the basal and alar laminæ. Within the basal lamina, likewise, are collected the neuroblasts which form the nuclei of origin of the efferent nerves; whilst within the alar lamina are developed the neuroblasts which constitute the nuclei of termination for the fibres of the afferent nerves.

As development proceeds, the two laminæ of the lateral wall fall outwards to a still greater extent, so that they come to lie very nearly in the same horizontal plane. In this manner their originally mesial or ventricular surfaces come to form the floor of the fourth ventricle. Even in the adult the groove, which separates the basal and alar laminæ so clearly from each other in the early condition, is more or less distinctly perceptible on the ventricular floor. It is represented by the fovea inferior and by the fovea superior. Between these depressions and the mesial groove on the floor of the fully-developed fourth ventricle there is an elongated elevation, which, in its lower part, forms the trigonum hypoglossi, above this the emenentia teres, whilst higher up it is continued towards the commencement of the Sylvian aqueduct. This clearly-marked and bulging mesial strip of the ventricular floor corresponds to the basal lamina, whilst the part of the floor which lies to the outer side of it and the two foveæ is derived from the alar lamina. The latter, therefore, includes the trigonum vagi, the area acustica, and the locus cœruleus.

The further development of the medulla takes place on the ventral aspect of the two laminæ by the deposition of new parts on those which are already formed. An oval bundle of longitudinal fibres makes its appearance on the outer surface of the alar lamina, at the point where this joins the basal lamina. This is the early fasciculus solitarius. It is composed of afferent fibres from the glossopharyngeal and vagus nerves. These, on reaching the surface of the medulla, turn downwards upon it. At first the connexion of the fasciculus solitarius with the medulla is very loose, and it may be regarded as being the equivalent in this part of the neural tube of the oval bundle of longitudinal fibres which, in the early cord, constitutes the first stage of the column of Burdach. Throughout the further stages of development the fasciculus solitarius indicates in a sufficiently clear manner the point of junction between the alar and basal laminæ. Very soon it becomes covered over by parts developed on its ventral aspect, and it ultimately comes to lie deeply in the substance of the medulla. This change in the position of the fasciculus solitarius with reference to the surface is associated with a striking developmental process which leads to certain remarkable results, and which is termed the formation of the **rhombic lip** of His (Fig. 422, B and C). Before the alar lamina falls outwards, while it still stands erect and its inner surface faces the corresponding surface of the opposite lamina, its dorsal edge is folded outwards and becomes fused with the outer surface of the remaining portion of the alar lamina. This

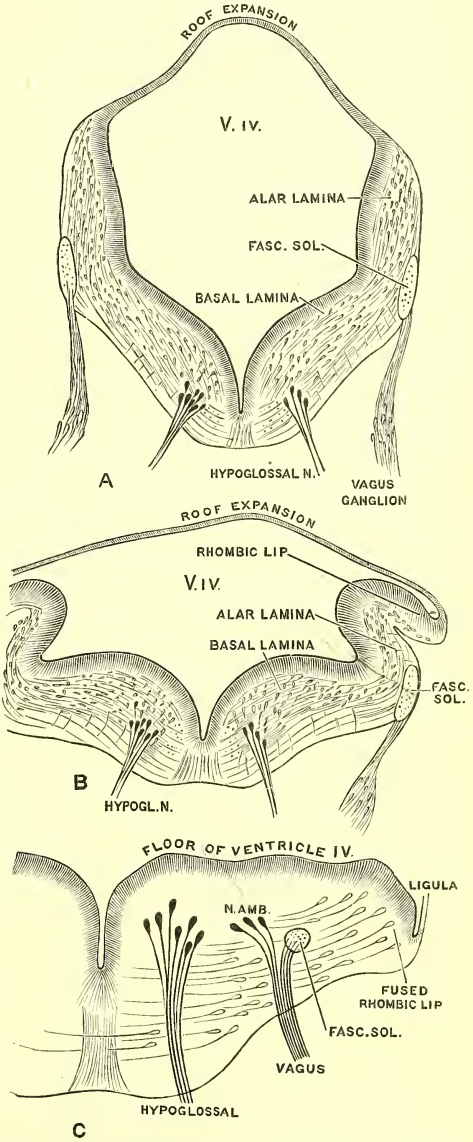


FIG. 422.—THREE STAGES IN THE DEVELOPMENT OF THE MEDULLA OBLONGATA (from His—slightly modified).

is the rhombic lip, and, when the fusion is complete, a multitude of neuroblasts take form within it and migrate in a forward and inwards direction into the ventral parts of the alar and basal laminæ. The mid-ventral lamina—which consists of spongioblastic cells alone, and which forms a narrow partition between the two basal laminæ—is reached on either side by the axons of many of these migrating cells. Whilst acting as an impassable barrier to the neuroblasts, this spongioblastic septum gives free passage from one side to the other to their axons, and a decussation of arcuate fibres in the mesial plane results. In this way the raphe of the medulla is formed. The process is very similar to that which takes place in the course of the formation of the anterior commissure of the cord, of which the raphe may be regarded as the equivalent in the medulla.

The development of the inferior olivary nucleus and of its two accessory parts is likewise closely connected with the migration of the neuroblasts from the region of the rhombic lip. Many of these cells collect together so as to form a nuclear lamella, which afterwards assumes its characteristic crumpled form.

As the neuroblasts of the rhombic lip stream inwards they pass both on the dorsal and the ventral aspects of the fasciculus solitarius, which thus comes to be covered over and separated from the surface. The spinal root of the trigeminal nerve, like the fasciculus solitarius, is also, in the first instance, throughout its entire course on the surface of the medulla, and its change of position in the greater part of its course within the pons and medulla is due to the subsequent development of those parts which cover it over.

The importance of the rhombic lip in the development of the medulla will be better appreciated if we enumerate the parts which spring from it: (1) the inferior olivary nuclei; (2) the cuneate nucleus; (3) the substantia gelatinosa Rolandi; (4) the arcuate nucleus; (5) the internal arcuate fibres; (6) the olivary system of fibres; (7) the restiform body. From this it is evident that the formation of the rhombic lip constitutes an extremely important step in the development of the human brain. Recent investigation, however, makes it clear that in most of the lower mammals the rhombic lip does not attain anything like the degree of prominence which it presents in the early brain of man.

The pyramidal tracts which come down from the cerebral cortex are late in making their appearance in the medulla. The formatio reticularis precedes them in development. They appear in the fourth month of fœtal life, and as they are developed the antero-median furrow between them takes form on the ventral aspect of the medulla.

His has pointed out that the earliest formed part of the medulla is the floor of the fourth ventricle, and that the other parts, speaking generally, are added in succession as we pass towards the surface. "The oldest layer of the medulla is the floor of the fourth ventricle with its nuclei. It is followed, in the first instance, by the reticular formation, and afterwards by the layer containing the olivary and other nuclei. Last of all come the pyramids and the outer (superficial) arcuate fibres" (His).

Pons Varolii.—The information which we possess at the present moment regarding the development of the pons Varolii is somewhat deficient; but there is little doubt that the course pursued is, in general, very similar to that which has been described for the medulla. It has been seen to be composed of parts which are in a great measure equivalent to those met with in the medulla, the formatio reticularis of the latter passing into the tegmental substance in the former, while the pyramids and arcuate nuclei and anterior superficial arcuate fibres of the medulla are represented by the large ventral part of the pons. Further, as His points out, similar relations between the chronological and local succession of layers may be recognised. Thus the primitive position of the motor nucleus of the trigeminal nerve, and also of its spinal root, is a superficial one, and it is only by a later process of development that the nucleus pontis and the thick layer of transverse and longitudinal fibres are formed.

From the phylogenetic point of view the tegmentum is the oldest part of the pons. The study of the comparative anatomy of the brain makes it evident that the large ventral part is comparatively a recent acquisition. As the cerebral cortex extends with the increasing evolution of the cerebral hemispheres (pallium), the ventral part of the pons is seen to keep pace with it in its development. This should easily be understood from what has been said in regard to its structure and connexions. It is composed of the nucleus pontis, the transverse fibres, and the pyramidal and cortico-pontine fibres, all of which stand in direct relation to the cerebral cortex. One of the striking features of the brain of a microcephalic idiot, where the cerebral cortex is greatly reduced, is the corresponding marked diminution in the size of the ventral part of the pons.

Cerebellum.—The roof of the fourth ventricle is formed for the most part by the thin epithelial layer already described as being formed by the expanded mid-dorsal lamina.

This does not stretch, however, over its entire extent. As we approach the upper part of the ventricle, it is seen to become continuous in the region of the isthmus with a thicker lamella. This lamella is bounded *above* by the intercrossing of the two trochlear nerves, which marks on the dorsal aspect of the neural tube the place of junction between the rhombencephalon and the mesencephalon; *below*, it is limited by a forwardly-directed semilunar fold of the thin epithelial ventricular roof, which takes place into the ventricular cavity at the level of the pontine flexure of the brain. The fold so constituted is termed the **plica choroidea**, seeing that mesoderm is introduced between its two layers, and this ultimately gives rise to the choroid plexus of the fourth ventricle (Fig. 425, A). The lamella which forms the roof or dorsal wall of the ventricle in front of the plica choroidea is developed into the cerebellum, and the superior medullary velum (valve of Vieussens).

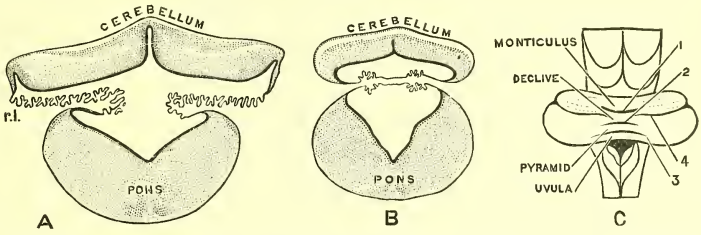


FIG. 423.—DRAWINGS TO ILLUSTRATE THE DEVELOPMENT OF THE CEREBELLUM (from Kuithan).

A. Transverse section through the forepart of the cerebellum of a sheep embryo.
B. Transverse section through the hinder part of the cerebellum of a sheep embryo.
C. Cerebellum of a human fœtus 17 cm. long.

1. Sulcus primarius.
2. Sulcus suprapyramidalis.
3. Sulcus infrapyramidalis.
4. Fissura post-lunata.

r.l. Lateral recess ventricle IV.

The cerebellar part of this lamella consists of two thick lateral plates which meet in the middle line and are joined there by an extremely thin dorsal seam or lamina (Fig. 423, A). The inner extremities of the two cerebellar plates are thus separated by a median groove, which opens into the cavity of the hind-brain (fourth ventricle). The statement, therefore, that the median lobe or vermis of the cerebellum is the most archaic part of the organ and is the part which is developed first is not supported by fact; indeed, the reverse of this is the case, because at this early stage the lateral portions are alone represented.

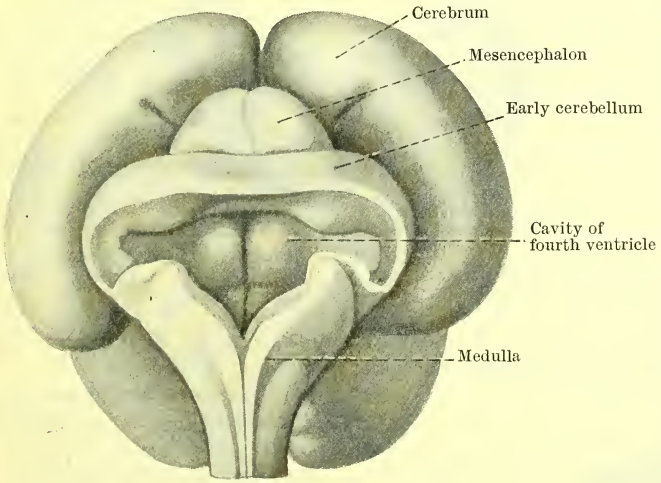


FIG. 424.—THE BRAIN OF AN EMBRYO OF ELEVEN WEEKS, viewed from behind to show the development of the cerebellum. At this stage the cerebellum is in the form of a simple band or plate which arches over the hinder aspect of the fore part of the cavity of the hind brain (from His).

In the course of time the inner ends of the cerebellar plates become fused in the middle line, and the median furrow between them disappears. In the process of this fusion the deep part of the intervening furrow remains enclosed within the substance of the median part of the cerebellum and persists for a short time as a minute cerebellar ventricle (Blake).

The cerebellum now presents the appearance of a simple uniform arch which bridges across the dorsal aspect of the upper part of the early fourth ventricle; and very soon the sulci begin to appear. Of late years the development and morphological import of these sulci have received much attention. Stroud, Kuithan, Blake, Elliot Smith, and Bradley have published valuable papers on this subject, and what is written here is largely gathered from the writings of these observers. Further, the terminology suggested by Elliot Smith has been chiefly, but not entirely, followed.

The first fissure to appear is the **floccular fissure**, which cuts off the postero-lateral corner of the cerebellar plate. The portion thus marked off is the **flocculus**, and its early appearance and relatively large size at this stage are significant of its high morphological

importance as a lobule of the cerebellum. The floccular fissure is continued inwards close to the posterior border of the cerebellar plate, joining its fellow of the opposite side in the middle line. Here it receives the name of **post-nodular fissure**. A narrow strip of cerebellar surface is thus marked out. The median part of this strip, by special growth, becomes the **nodulus**, whilst the part which extends between this and the flocculus remains narrow and band-like, and ultimately forms a portion of the inferior medullary velum.

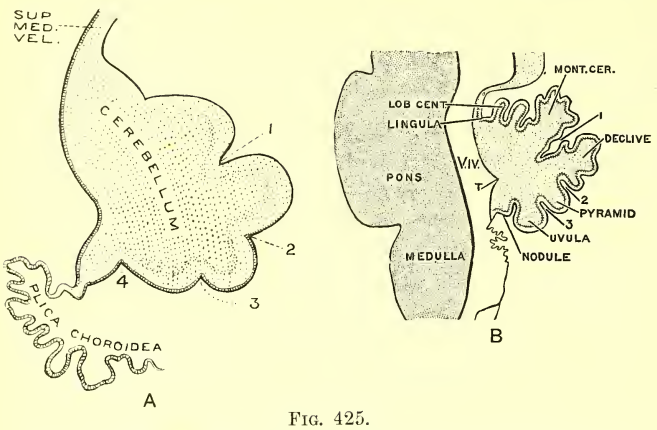


FIG. 425.

A. Mesial section through the cerebellum of an early human fœtus (semi-diagrammatic).
B. Mesial section through the cerebellum of a human fœtus 17 cm. long (from Kuithan).

1. Fissura prima.
2. Fissura suprapyramidalis.
3. Fissura infrapyramidalis.
4. Fissura postnodularis.
T. Transverse groove on the roof of the fourth ventricle.

The next furrow which appears is the **sulcus primarius** (Kuithan) or **fissura prima** (Elliot Smith). It cuts deeply into the vermis in a transverse direction between the culmen monticuli and the clivus monticuli, and is then carried outwards over each hemisphere so as to separate the two crescentic lobules. The fissura prima is the deepest of all the fissures of the vermis, and it is developed towards the end of the third month. A little later two other furrows are observed in the vermis. These are the **suprapyramidal** and the **infrapyramidal** (the fissura secunda of Elliot Smith). By the former the pyramid is limited above; by the latter the pyramid is separated from the uvula.

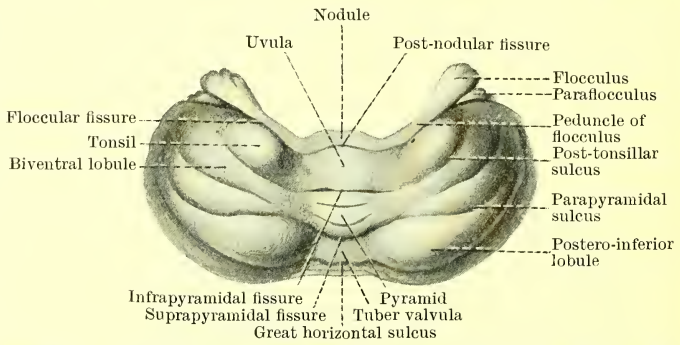


FIG. 426.—UNDER SURFACE OF THE CEREBELLUM OF A HUMAN FŒTUS WHICH HAS REACHED THE END OF THE FIFTH MONTH OF DEVELOPMENT.

After the main fissures of the vermis are established, four important sulci on the surface of each cerebellar hemisphere come into view, viz. the postlunate, the post-tonsillar, the parapyramidal, and the great horizontal sulci.

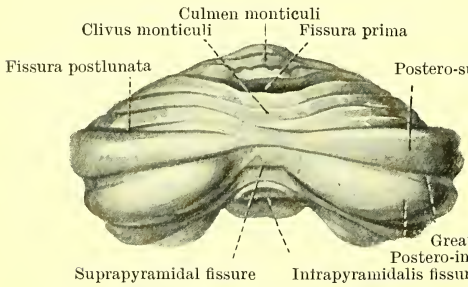


FIG. 427.—CEREBELLUM OF A HUMAN FŒTUS WHICH HAS REACHED THE END OF THE FIFTH MONTH OF DEVELOPMENT. Viewed from above and behind.

The **fissura postlunata** appears in the fourth month, and curves inwards on the upper surface of the organ behind the posterior crescentic lobule. In many cases it becomes confluent with its fellow of the opposite side behind the clivus monticuli. The **post-tonsillar fissure** is seen on the under surface of the cerebellum about the beginning of the fifth month. It circumscribes the prominent and conspicuous tonsil and becomes confluent with the fissura infrapyramidalis. The **parapyramidal fissure** appears on the under surface of the cerebellar hemisphere behind the biventral lobule, and usually joins the suprapyramidal fissure of the inferior vermis.

The **great horizontal fissure**, in spite of its depth in the adult brain—a depth which is due to the excessive growth in the later months of development of the two lobules that bound it—appears very late in the development of the cerebellum. It is first seen as a very broad shallow groove or furrow on the outer margin of the hemisphere. From this it runs forwards to the middle peduncle and backwards towards the vermis, where it usually joins the postlunate fissure. At this stage there is no folium cacuminis, so that the combined portion of the postlunate and great horizontal fissures intervenes between the clivus monticuli and the tuber valvulæ. Even at the time of birth the folium cacuminis is not seen on the surface. It rises up from the bottom of the combined portions of the great horizontal and postlunate fissures so as to form a barrier between them.

Very early a transverse groove appears on the smooth anterior or ventricular surface of the cerebellum (Fig. 425, B, T). This is placed much nearer the lower than the upper border of the organ, and it represents at this stage the angular peak of the tent-like roof of the fourth ventricle in the adult brain. As growth goes on, the portions of the cerebellum in front and behind this groove approach each other, so as to deepen the groove and bring about the backward prolongation of the ventricular cavity towards the cerebellum.

The leading distinctive characters of the human cerebellum are: (1) the small size of the flocculus; (2) the large size of the tonsil; (3) the excessive development of the lateral hemisphere, and particularly of the postero-superior and postero-inferior lobules which bound the great horizontal fissure.

THE MESENCEPHALON.

The mesencephalon or mid-brain is the short, narrow part of the brain-stem which occupies the aperture of the tentorium cerebelli (incisura tentorii), and connects the cerebrum which lies above with the parts which occupy the posterior cranial fossa. It is about three-quarters of an inch in length, and it consists of a dorsal part, composed of the **corpora quadrigemina**, and a much larger ventral part, which is formed by the two **crura cerebri**.

In the undissected brain the corpora quadrigemina are completely hidden from view by the splenium of the corpus callosum, which projects backwards over them, and also by the superimposed cerebral hemispheres. The hinder end of each optic thalamus likewise, to some extent, overhangs the upper part of the mesencephalon on its dorsal and lateral aspect (Fig. 388, p. 482). On this portion of the optic thalamus are seen two projections, which are specially related to the mesencephalon. These are the cushion-like **pulvinar**, which forms the inner and hinder part of the thalamus, and the **corpus geniculatum externum**, an ill-defined oval swelling on the outer and under aspect of the posterior end of the thalamus.

The crura cerebri can to some extent be seen on the base of the brain, where they bound the posterior part of the interpeduncular space. Encircling the upper end of each crus cerebri, where it plunges into the cerebrum, is the optic tract (Fig. 380, p. 474).

The mesencephalon is tunnelled from below upwards by a narrow passage, called the **aqueduct of Sylvius**, which connects the fourth ventricle with the third ventricle (Fig. 429, p. 533). This channel lies much nearer the dorsal than the ventral aspect of the mesencephalon.

Corpora Quadrigemina.—This name is applied to four rounded eminences on the posterior aspect of the mesencephalon (Fig. 388, p. 482). The **superior pair** are larger and broader than the **inferior pair**, but they are not so well defined nor are they so prominent. A longitudinal and a transverse groove separate the quadrigeminal bodies from each other. The longitudinal groove occupies the mesial plane and extends upwards to the posterior commissure of the brain. The upper end of this groove widens out into a shallow depression, in which the **pineal body**, a small conical structure which belongs to the diencephalon, rests. From the lower end of the same groove a short but well-defined and projecting band, the **frenulum veli**, passes to the valve of Vieussens, which lies immediately below the inferior pair of quadrigeminal bodies. The transverse groove curves round below each of the superior pair of quadrigeminal bodies and separates them from the inferior pair. It is also continued in an upward and forward direction on the lateral aspect of the mesencephalon.

The quadrigeminal bodies are not marked off laterally from the sides of the mesencephalon, but each has in connexion with it, on this aspect, a prominent strand of white matter, which is prolonged upwards and forwards under the projecting pulvinar and corpus geniculatum externum. These strands are called the **brachia of the corpora quadrigemina**, and they are separated from each other by a continuation on the side of the mesencephalon of the transverse groove, which intervenes between the two pairs of bodies.

The **corpus geniculatum internum** (corpus geniculatum mediale) is closely associated with the brachia. It is a small, sharply-defined oval eminence, which lies on the side of the upper part of the mesencephalon under shelter of the pulvinar of the optic thalamus.

The **inferior brachium** (brachium quadrigeminum inferius), proceeding upwards from the lower quadrigeminal body, advances towards the corpus geniculatum internum and disappears from view under cover of this prominence. Upon the opposite side of the same geniculate body the mesial root of origin of the optic tract takes shape on the surface, and the appearance is such that the conclusion might very naturally be arrived at that the inferior brachium and this root of the optic tract are continuous with each other under the geniculate elevation. This is not the case, however; the fibres of the inferior brachium, to a large extent, proceed into the subjacent tegmentum under cover of the internal geniculate body and help to constitute an ascending tract from the inferior quadrigeminal body, which proceeds upwards to the optic thalamus. Of the fibres of the mesial root of the optic tract some end in the gray matter of the internal geniculate body, whilst others arise within it. They constitute what is called **Gudden's commissure.**

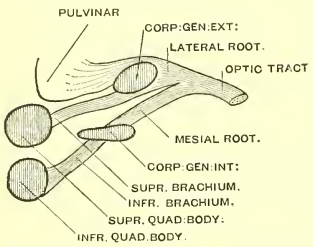


FIG. 428.—DIAGRAM OF THE ROOTS OF THE OPTIC NERVE.

The **superior brachium** (brachium quadrigeminum superius) is carried upwards and forwards between the overhanging pulvinar and the corpus geniculatum internum. A surface examination of the mesencephalon is sufficient to show that, while a large part of this strand enters the corpus geniculatum externum, a considerable portion runs into the lateral root of the optic tract.

The **optic tract** is thus attached to the brain-stem by two roots, viz. a mesial and a lateral, which are separated from each other by a distinct groove. The **mesial root** disappears under the internal geniculate body. The **lateral root** spreads out and some of its fibres enter the superior quadrigeminal body through its brachium, whilst others find their way into the corpus geniculatum externum and the pulvinar of the optic thalamus (Fig. 428).

Crura Cerebri (pedunculi cerebri).—The crura cerebri constitute the chief bulk of the mesencephalon (Fig. 429, p. 533). Upon the basal aspect of the brain they appear as two large rope-like strands, which emerge close together from the upper aspect of the pons Varolii and diverge as they proceed upwards to enter the cerebrum. At the place where each crus disappears into the corresponding side of the cerebrum, it is encircled by the optic tract.

Each crus cerebri is composed of two parts, viz. a **dorsal tegmental part** (tegmentum), which is prolonged upwards into the region below the optic thalamus (subthalamic tegmental region), and a **ventral pedal portion** or **crusta** (basis pedunculi), which, when traced upwards into the cerebrum, is seen to take up a position on the outer side of the optic thalamus and to be continuous with the internal capsule of the brain. When the base of the brain is examined it is the crusta which is seen, and it is observed to be white in colour and streaked in the longitudinal direction. In the tegmentum the longitudinally-arranged fibres are, for the most part, *corticipetal*, or, in other words, fibres which are ascending towards the cortex of the cerebrum; the crusta, on the other hand, is entirely composed of longitudinal strands of fibres which are *corticifugal*, or fibres which descend from the cortex cerebri.

On the surface of the mesencephalon the separation between the tegmental and

pedal portions of the crus cerebri is clearly indicated by an inner and an outer groove. The inner or mesial furrow is the more distinct of the two. It looks into the interpeduncular space, and from it emerge the fascicles of the third or oculo-motor nerve. It is, therefore, termed the **sulcus oculo-motorii** (sulcus nervi oculo-motorii). The outer groove, which is placed on the lateral aspect of the mesencephalon, receives the name of the **sulcus lateralis mesencephali.** When traced downwards, it is observed to become continuous with the furrow which intervenes between the middle and superior peduncles of the cerebellum.

A close inspection of the outer surface of the tegmental part of the crus cerebri, below the level of the quadrigeminal brachia, will reveal some faintly-marked bundles of fibres curving obliquely upwards and backwards to reach the inferior quadrigeminal body (Fig. 390, p. 484). These are fibres of the **lateral fillet**, coming to the surface at the sulcus lateralis and sweeping over the subjacent superior cerebellar peduncle to gain the inferior quadrigeminal body.

INTERNAL STRUCTURE OF THE MESENCEPHALON.

When transverse sections are made through the mesencephalon the aqueduct of Sylvius is seen to be surrounded by a thick layer of gray matter, which receives the name of the **Sylvian gray matter** or the **central gray matter of the aqueduct** (stratum griseum centrale). On the dorsal aspect of the Sylvian gray matter the corpora quadrigemina form a layer which separates it from the surface, and to which the term **lamina quadrigemina** is applied. On the ventral and lateral aspects of the Sylvian gray matter are the tegmental portions of the crura cerebri; whilst, intervening between each of the latter and the corresponding crusta, there is a conspicuous mass of dark pigmented matter termed the **substantia nigra.**

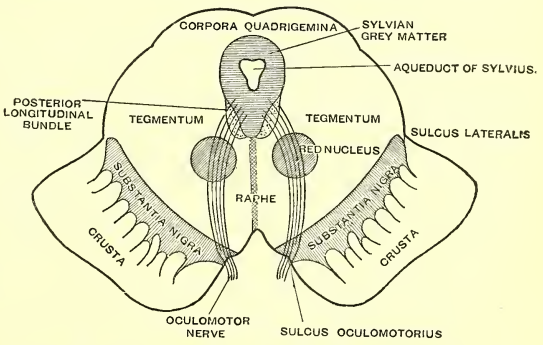


FIG. 429.—DIAGRAMMATIC VIEW OF THE CUT SURFACE OF A TRANSVERSE SECTION THROUGH THE UPPER PART OF THE MESENCEPHALON.

Sylvian Aqueduct and Sylvian Gray Matter (aquæductus cerebri —stratum griseum centrale).—The aqueduct of Sylvius is the canal which leads from the fourth ventricle below, upwards through the mesencephalon, to the third ventricle above. It is not quite three-quarters of an inch in length, and it lies much nearer the dorsal than the ventral surface of the mesencephalon. When examined in transverse section, it presents a triangular outline as it passes into the fourth ventricle and a T-shaped outline close to the third ventricle. In the intermediate part of its course it assumes different outlines, and not always the same form at the same level in different individuals.

The aqueduct of Sylvius is lined by ciliated epithelium, and outside this is the thick layer of Sylvian gray matter, which is directly continuous below with the gray matter spread out on the floor of the fourth ventricle, and above with gray matter on the floor and sides of the third ventricle. Scattered more or less irregularly throughout the Sylvian gray matter are numerous nerve-cells of varying forms and sizes, whilst in addition to these there are three definite collections or clusters of cells, which constitute the nuclei of origin of the trochlear nerve, the oculo-motor nerve, and the mesencephalic root of the trigeminal nerve. The position and relations of these will be given at a later stage.

Substantia Nigra.—When seen in transverse section, the substantia nigra presents a semilunar outline. It consists of a mass of gray matter, in the midst of which are large numbers of deeply pigmented nerve-cells. It is only when this substance is examined in bulk that it appears dark; in thin sections it does not differ much in colour from ordinary gray matter, although, under the microscope, the brown-coloured cells stand out very conspicuously, even under low powers.

The substantia nigra is disposed in the form of a thick layer, interposed between the tegmental and pedal portions of the crus cerebri. It begins below at the upper border of the pons Varolii and extends upwards into the subthalamic region. The margins of this layer of dark-coloured substance come to the surface at the oculo-motor and the lateral sulci of the mesencephalon, and its inner part is traversed by the emerging fascicles of the oculo-motor nerve. It is not equally thick throughout. Towards the lateral sulcus it becomes thin, whilst it thickens considerably near the inner aspect of the crus cerebri. The surface of the substantia nigra, which is turned towards the tegmentum, is concave and uniform; the opposite surface is convex and rendered irregular by the presence of numerous slender prolongations of the substance into the crusta.

The morphological and physiological significance of the substantia nigra is not fully understood, and the connexions established by its cells are imperfectly known.

Inferior Quadrigeminal Bodies (colliculi inferiores).—Each of the inferior quadrigeminal bodies is largely composed of a mass of gray matter which, in transverse section, presents an oval outline (Fig. 432, p. 537). This central nucleus is, to a large extent, encapsulated by white matter. Numerous cells of different sizes are scattered throughout it, and the whole mass is pervaded by an intricate interlacement of fine fibres, which, to a large extent, are derived from the lateral fillet and the inferior brachium.

In transverse sections, through this region, the lateral fillet is seen to abut against the outer margin of the central nucleus. Many of the fibres of this tract enter it at once and become dispersed amongst its cells; others sweep over its dorsal surface, so as to give it a superficial covering; whilst a third group is carried in the form of a thin layer inwards on its ventral aspect, so as to mark it off from the subjacent Sylvian gray matter of the aqueduct (Fig. 432, p. 537). In this manner, therefore, the inferior quadrigeminal nucleus becomes partially circumscribed by the fibres of the lateral fillet. Several of the lateral fillet fibres, which proceed over the superficial or dorsal aspect of the nucleus, reach the mesial plane and form a loose decussation with the corresponding fibres of the opposite side.

The intimate connexion which is thus exhibited between the fibres of the lateral fillet and the nucleus of the inferior quadrigeminal body is very significant. It has already been shown that the lateral fillet, to a large extent, comes from the nuclei of termination of the cochlear nerve of the opposite side, although most of its fibres have to pass through several nuclear internodes before they reach the inferior quadrigeminal body. We must associate, therefore, the inferior quadrigeminal body, and also the corpus geniculatum internum, which likewise receives lateral fillet fibres, with the organ of hearing.

This view of the inferior quadrigeminal bodies is supported both by experimental and by morphological evidence. Speaking broadly, it may be stated that the inferior quadrigeminal bodies are only present as distinct eminences in mammals, and then they are invariably correlated with a spirally-wound and well-developed cochlea. That they have nothing to do with sight, is shown by the fact that, when the eyeballs are extirpated in a young animal, the inferior quadrigeminal bodies remain unaffected, whilst the superior quadrigeminal bodies after a time atrophy (Gudden). When, on the other hand, the cochlear terminal nuclei are destroyed, fibres which have undergone atrophy may be followed to the inferior quadrigeminal bodies of both sides, but particularly to that of the opposite side (Baginski, Bumm, and Ferrier and Turner). A very considerable tract of ascending fibres takes origin within the inferior quadrigeminal body and passes upwards, in the inferior brachium, into the tegmentum subjacent to the internal geniculate body. Within the tegmentum they proceed up to the optic thalamus (Ferrier and Turner).

Superior Quadrigeminal Bodies (colliculi superiores).—The superior quadrigeminal body presents a more complicated structure (Fig. 431). Superficially, it is coated with a very thin layer of white matter, which is termed the **stratum zonale**. Underneath this there is a gray nucleus, called the **stratum cinereum**, which in transverse section exhibits a crescentic outline and rests in a cap-like manner upon the subjacent part of the eminence. The succeeding two strata, which respectively receive the names of **stratum opticum** and the **stratum lemnisci**, present this feature in common, that they are composed of gray matter, traversed by numerous fibres. The source from which the fibres are derived differs, however, in each case.

Nerve-fibres reach the superior quadrigeminal body through—(1) the lateral and mesial fillets, and (2) through the superior brachium. The **fillet fibres** enter

the stratum lemnisci, and, in all probability, end there. The **superior brachium** contains fibres of two different kinds, viz. fibres from the optic tract and fibres from the cortex of the occipital lobe of the cerebrum. By the former it is connected with the retina, and by the latter with the visual centre in the occipital region of the cerebral cortex. The *retinal fibres*, for the most part, spread out on the surface of the quadrigeminal body and form the stratum zonale. Most of them dip down into the substance of the body and end in connexion with the cells of the deeper layers; several, however, are carried across the mesial plane, to end in the superior quadrigeminal body of the opposite side. The *occipital fibres*, and probably also some of the retinal fibres, enter the stratum opticum. The fibres from the occipital cortex form part of the optic radiation, and the course which they pursue will be dealt with later on.

Tegmental Portions of the Crura Cerebri (tegmenta).—The tegmentum of the crus cerebri may be regarded as the continuation upwards of the formatio reticularis of the medulla and the dorsal or tegmental portion of the pons into the mesencephalon. It therefore consists of fine bundles of longitudinal fibres intersected by arching fibres, which take a transverse and curved course. The interstices between these nerve-bundles is occupied by gray matter containing irregularly scattered nerve-cells. On its dorsal aspect the tegmentum is continuous, at the side of the Sylvian gray matter, with the bases of the corpora quadrigemina, whilst ventrally it is separated from the crusta by the substantia nigra. The two tegmenta of opposite sides are, to some extent, marked off from each other in the mesial plane by a prolongation upwards of the median raphe of the pons and medulla, although, in the lower part of the mesencephalon, this is much obscured by the decussation of the superior peduncles of the cerebellum. The two longitudinal strands, termed the **posterior longitudinal bundle** and the **fillet**, are prolonged upwards throughout the entire length of the mesencephalon; and they present the same relations to the tegmentum as in the lower parts of the brain. The former is placed in relation to its dorsal aspect, whilst the fillet is carried up in its ventral part.

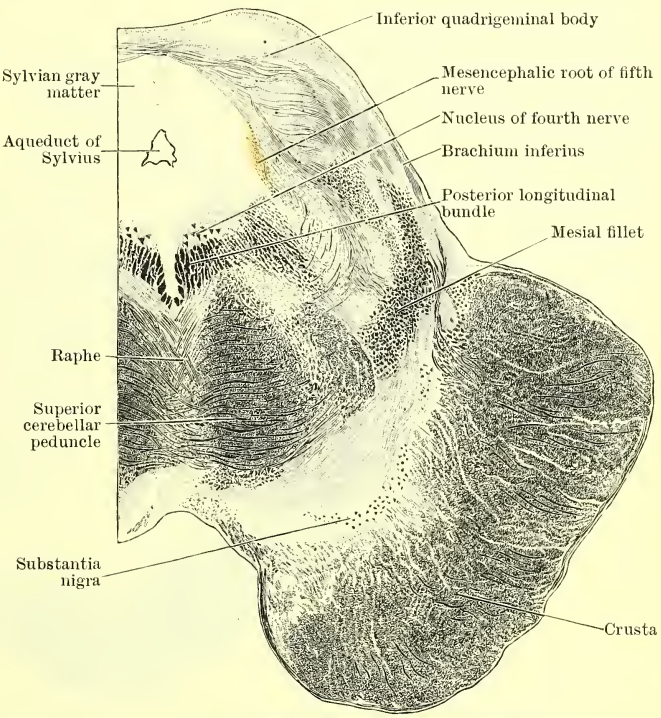


Fig. 430.—Transverse Section through the Human Mesencephalon at the Level of the Inferior Quadrigeminal Body.

The tegmentum of the crus cerebri may be considered as presenting two parts: viz. (1) a lower part, which is placed subjacent to the inferior quadrigeminal bodies and which is largely occupied by the decussation of the superior cerebellar peduncles (Fig. 430); and (2) a superior part, subjacent to the superior quadrigeminal bodies, which is traversed by the emerging bundles of the third nerve and which contains a large and striking nuclear mass, termed the nucleus ruber or the red tegmental nucleus (Fig. 431). In the lower part of the mesencephalon is the nucleus of the fourth nerve; in the upper part, the nucleus of the third nerve.

Superior Cerebellar Peduncles (brachia conjunctiva).—As the superior cere-

bellar peduncles leave the pons and sink into the tegmenta of the mesencephalon, they undergo a complete decussation subjacent to the inferior quadrigeminal bodies and the Sylvian gray matter (Figs. 407, p. 505; 432, p. 537; and 430, p. 535). In this manner each peduncle is transferred from one side, across the mesial plane, to the opposite side. The decussation is completed at the level of the upper borders of the inferior quadrigeminal bodies, and then each peduncle proceeds upwards into the superior part of the tegmentum, where it encounters the red nucleus. Into this a large proportion of its fibres plunge and come to an end in connexion with the nuclear cells. Many of the peduncular fibres, however, are carried around the nucleus so as to form for it a capsule which is thicker on the inner than on the outer side (Fig. 431). These are prolonged into the subthalamic region, and ultimately penetrate the ventral aspect of the optic thala-

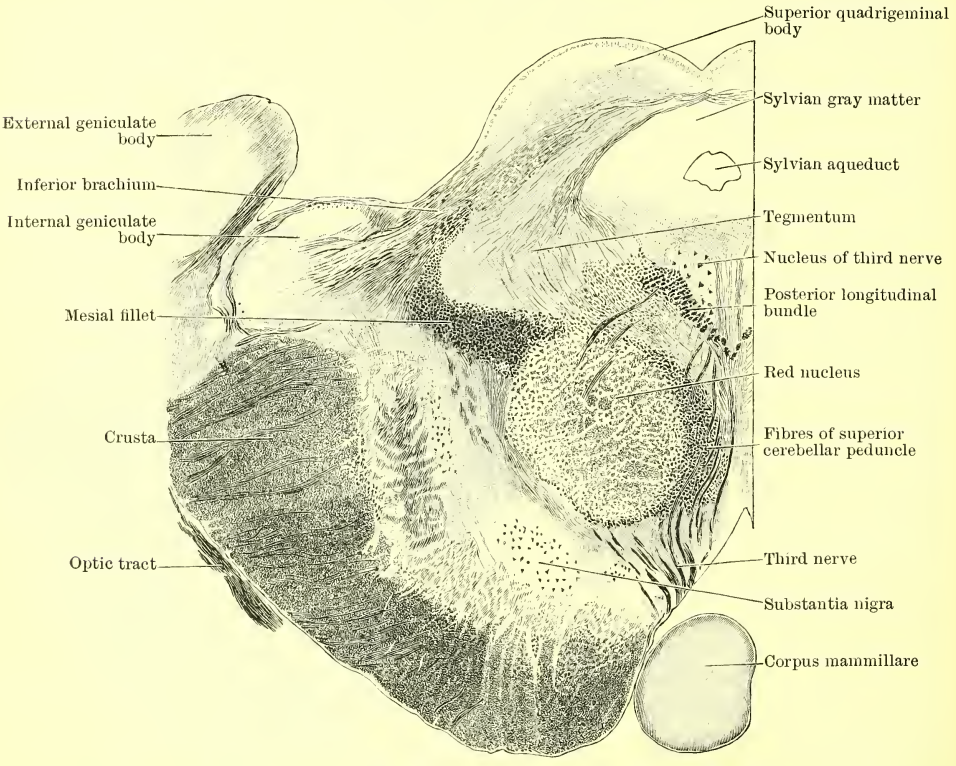


Fig. 431.—Transverse Section through the Human Mesencephalon at the Level of the Superior Quadrigeminal Body.

mus, where they end in connexion with the thalamic cells. The superior cerebellar peduncle is, therefore, a great efferent tract which issues from the lateral hemisphere of the cerebellum, crosses the mesial plane in the lower part of the mesencephalon, and ends in the red nucleus and the ventral part of the optic thalamus.

Red Nucleus (nucleus ruber).—This is a rounded nuclear mass, of a reddish tint in the fresh brain, which lies in the upper part of the tegmentum, and in the path of the superior cerebellar peduncle. In transverse section it presents a circular outline. It begins at the level of the lower border of the superior quadrigeminal body and it extends upwards into the subthalamic tegmental region. At first it is small and is placed at a little distance from the mesial plane; but as it proceeds towards the subthalamic region, it increases in bulk and approaches more nearly to the mesial raphe, and its neighbour of the opposite side. The curved emerging bundles of the third nerve pass through it on their way to the surface. The relation which the fibres of the opposite superior cerebellar peduncle present to it has been described. These fibres traverse its lower part in such numbers that in Weigert-Pal specimens it presents a very dark colour; but higher up, as the fibres

are gradually absorbed by the nuclear mass, they become less numerous in its midst, and the nucleus assumes a paler tint.

Numerous fibres which descend from the cerebral cortex and others from the corpus striatum enter the red nucleus. It likewise sends out fibres which proceed in two directions: (1) upwards into the thalamus; (2) downwards to the spinal cord. The former may be regarded as carrying on the continuity of the superior cerebellar path after its internodal interruption in the red nucleus. The fibres to the spinal cord, called the *rubro-spinal tract* and first described by Monakow, cross to the opposite side and then descend in the tegmentum to reach the lateral column of the cord.

Posterior Longitudinal Fasciculus.—This is a very conspicuous tract of longitudinal fibres which extends throughout the whole length of the medulla, pons, and mesencephalon, in the formatio reticularis or tegmental part of each. Below, at the level of the decussation of the pyramids, it becomes continuous with the anterior basis-bundle of the spinal cord (p. 491), whilst, by its opposite or upper end, it establishes intricate connexions in the region immediately above the mesencephalon. Throughout its whole length it lies close to the mesial plane and its fellow of the opposite side. In the mesencephalon it is applied to the ventral aspect of the Sylvian gray matter, whilst in the pons and medulla it is situated immediately subjacent to the gray matter of the floor of the fourth ventricle. One of its most salient features is the intimate association which it presents with the three motor nuclei from which the nerves for the supply of the muscles of the eyeball take origin, viz. the oculo-motor or third nucleus, the trochlear or fourth nucleus, and the abducent or sixth nucleus. The first two of these are closely applied to its inner and dorsal aspect, whilst the abducent nucleus is placed on its outer side. Into each of these nuclei it sends many collaterals, and probably also some of its constituent fibres, and these end in terminal arborisations around the nuclear cells. It would appear, therefore, that one of the most important functions of this strand is to bind together these nuclei, and thus enable them to act in harmony with each other. Fibres also enter the posterior longitudinal fasciculus from the auditory system and perhaps, also, from the facial and other motor nuclei. The results obtained by degeneration would seem to indicate that, to a large extent, it is formed of fibres which run a short course within it.

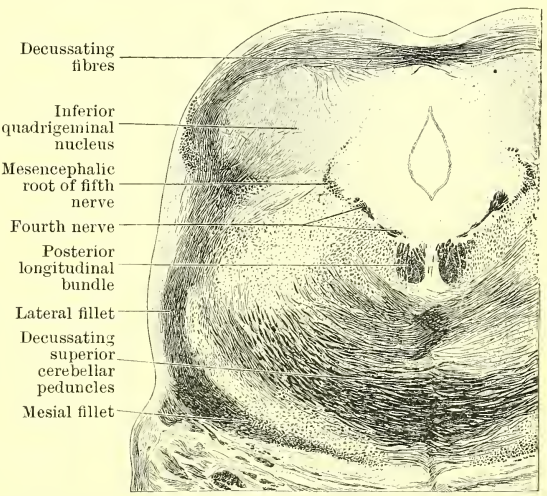


Fig. 432.—Section through the inferior Quadrigeminal Body and the Tegmentum of the Mesencephalon below the Level of the Nucleus of the Fourth Nerve in the Orang. (The decussation of the superior cerebellar peduncles and the course of the fourth nerve in the Sylvian gray matter are seen.)

In spite of the large amount of attention which has been given to the study of the posterior longitudinal bundle, it must be admitted that there is little unanimity of opinion regarding its connexions and functions. That it is a brain tract of high importance, is evident from the fact that it is present in all vertebrates, and, further, that its fibres assume their medullary sheaths at an extremely early period. In fish, amphibians, and reptiles, it is one of the most powerful bundles of the medulla. In man its fibres medullate between the sixth and seventh months of fœtal life, and at the same time as the fibres of the anterior basis-bundle of the cord, with which it stands in connexion.

According to Van Gehuchten and Edinger, it extends upwards beyond the level of the oculo-motor nucleus, and in the subthalamic region its fibres take origin from a special nucleus of its own in the gray matter of the third ventricle, immediately below the level of the corpora mammillaria. Fibres also enter the posterior longitudinal bundle from a nucleus common to it and the posterior commissure of the brain. This nucleus is placed in the fore-part of the Sylvian gray matter of the mid-brain. Held asserts that numerous fibres, arising from cells in the superior quadrigeminal body, curve in an arcuate manner in the tegmentum outside the Sylvian gray

matter, to take part on the ventral aspect of this in what is called the "fountain decussation." Reaching the opposite side these fibres turn downwards and join the posterior longitudinal fasciculus. The same authority considers that fibres from the ventral part of the posterior commissure can also be traced downwards into the posterior longitudinal bundle. Edinger, on the other hand, places these fibres as a distinct tract on the ventral and lateral aspect of the posterior longitudinal bundle, although in apposition with it.

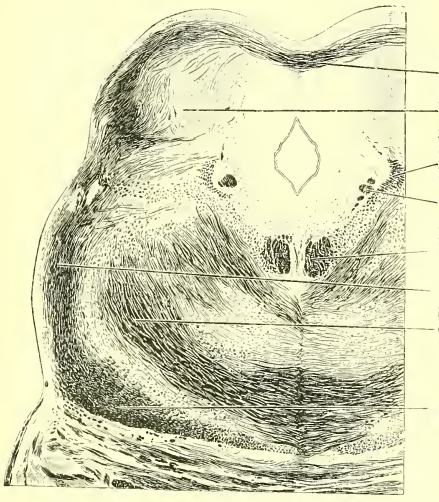


FIG. 433.—SECTION THROUGH THE INFERIOR QUADRIGEMINAL BODY AND THE TEGMENTUM OF THE MESENCEPHALON, AT A SLIGHTLY LOWER LEVEL THAN FIG. 432.

Mendel believes that fibres from the oculo-motor nucleus are carried down in the posterior longitudinal bundle, and, from this, into the facial nerve for the supply of the orbicularis palpebrarum and the corrugator supercilii, bringing these muscles therefore under the control of the same nucleus as the levator palpebræ superioris muscle. This view has received corroboration at the hands of Tooth and Turner. It has been further suggested that fibres from the hypoglossal nucleus may, by the posterior longitudinal fasciculus, reach the facial nerve, and through it the orbicularis oris. In this manner the same nucleus would hold sway over the tongue and the sphincter muscle of the lips. The close relation which exists between the ascending part of the intrapontine portion of the facial nerve and the posterior longitudinal bundle would render the passage of fibres from one to the other a matter which could easily be understood. Another interchange of fibres through the posterior longitudinal bundle has been described by Duval and Laborde. According to these authorities, fibres from the abducent nucleus ascend in the posterior longitudinal bundle into the mesencephalon, and establish connexions with that part of the oculo-motor nucleus from which the nerve for the internal rectus of the opposite side derives its fibres. If this view be correct, it affords a ready and simple anatomical explanation of the harmonious action of the external and internal recti muscles in producing movements of the two eyeballs simultaneously to the right and to the left. From the investigations of E. H. Fraser it would appear that no fibres from the abducent nucleus go directly into the oculo-motor nerve. The same observer has shown that many fibres from Deiters' nucleus, through the path afforded by the posterior longitudinal bundle, enter the third and the fourth nuclei.

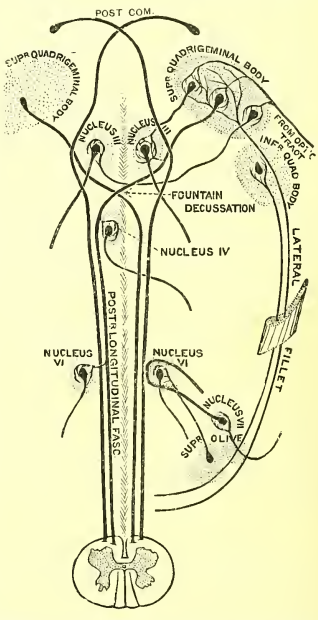


FIG. 434.—DIAGRAM OF THE CONNEXIONS OF THE POSTERIOR LONGITUDINAL BUNDLE (after Held—modified).

Lateral Fillet (lemniscus lateralis).—The lateral fillet is a definite tract of longitudinal fibres, which extends upwards through the lateral part of the tegmental substance of the upper portion of the pons and the mesencephalon. It is formed by the fibres of the corpus trapezoides in the lower part of the pons, abruptly turning upwards and taking a course towards the quadrigeminal region. Entering into its constitution, therefore, are fibres from several sources, viz. (1) from the terminal cochlear nuclei of the opposite side; (2) from the terminal cochlear nuclei of the same side; (3) from the superior olivary nuclei. As the tract proceeds upwards a continuation of the gray matter of the superior olivary nucleus is carried up in connexion with it to form the nucleus of the lateral fillet, and from this fibres are also added to the strand. In the mesencephalon the fibres of the lateral fillet end in the nucleus of the inferior quadrigeminal body (p. 534) and in the gray substance of the corpus geniculatum internum, whilst a few are carried into the superior quadrigeminal body. The fibres which go to the inferior quadrigeminal body sweep outwards round the outer side of the superior cere-

bellar peduncle, and to some extent appear on the surface of the mesencephalon (p. 533).

But the lateral fillet cannot be considered as a tract composed entirely of ascending fibres belonging to the auditory system. It also contains descending fibres, the connexions and functions of which are not fully understood. These have been traced by Ferrier and Turner through the pons and medulla into the lateral column of the cord.

Mesial Fillet (lemniscus mesialis).—The mesial fillet has already been followed through the medulla and pons, and its position in each of these portions of the brain-stem has been defined (pp. 493 and 504). In the tegmentum of the lower part of the mesencephalon it is carried up in the form of a more or less flattened band on the ventral aspect of the decussating superior cerebellar peduncles. To its outer side, and forming an angle with it (as seen in transverse section), is the lateral fillet (Figs. 432 and 433), and at this level there is no clear demarcation between these two tracts. In the upper part of the mesencephalon the appearance of the red nucleus in the tegmentum causes the mesial fillet to take up a more lateral and dorsal position, so that it now comes to lie subjacent to the corpus geniculatum internum (Fig. 431, p. 536). At this level it exhibits a crescentic outline in transverse section, and the lateral fillet has to a large extent disappeared from its outer side.

The mesial fillet takes origin in the lower part of the medulla oblongata from the gracile and cuneate nuclei of the opposite side (p. 493). Seeing that the posterior column of the cord ends in these nuclei, the fillet may be considered to continue that column upwards into the brain. In the mesencephalon a considerable contribution of fibres is given by the mesial fillet to the superior quadrigeminal body, and then the remainder of the tract proceeds through the subthalamic tegmental region into the hinder part of the lateral nucleus of the optic thalamus. Here its fibres end in terminal arborisations around the thalamic cells.

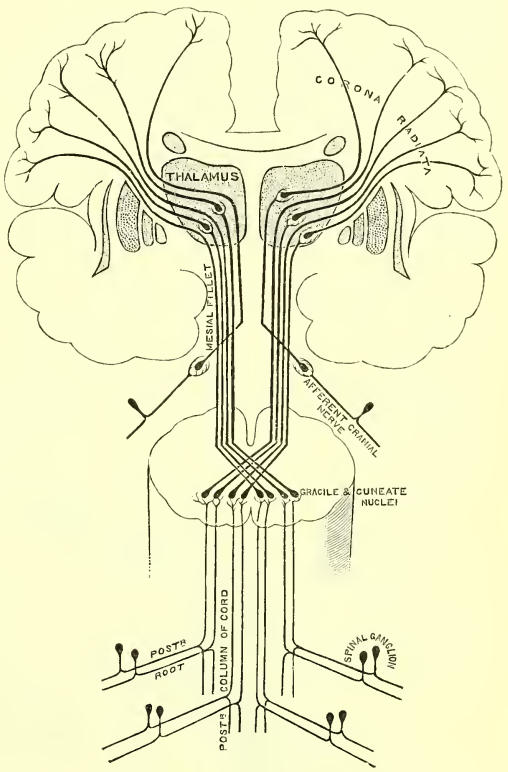


Fig. 435.—Diagram of the Connexions of the Mesial Fillet and also of certain of the Thalamo-cortical Fibres.

Ganglion Interpedunculare and Fasciculus Retroflexus.—On the ventral aspect of the tegmentum, close to the surface and to the mesial plane, there is a small group of cells in the lower part of the gray matter which forms the locus perforatus posticus. This is termed the *ganglion interpedunculare.*

The *fasciculus retroflexus* is a small band of fibres which arises above in the ganglion habenulæ—a nuclear mass which will be studied in connexion with the diencephalon—and which runs downwards and forwards in the tegmentum of the upper part of the mesencephalon between the inner aspect of the nucleus ruber and the mesial plane, to end in the ganglion interpedunculare.

Fountain Decussation.—If the region in front of the posterior longitudinal bundles be examined in the upper part of the mesencephalon a very close decussation of fibres in the mesial plane will be observed in the interval between the two red nuclei. This is the "fountain decussation." According to Held, the fibres which take part in the dorsal portion of the fountain decussation (decussation of Meynert) come from the superior quadrigeminal bodies, and, after they have gained the opposite side, they turn downwards in the posterior longitudinal fasciculus. The ventral part of the decussation (decussation of Forel) would appear to be formed by arcuate fibres of the tegmentum which arise in the gray matter of the Sylvian aqueduct.

Crusta or Pes of the Crus Cerebri (basis pedunculi).—The crusta presents a

somewhat crescentic outline when seen in section, and it stands quite apart from its fellow of the opposite side. It is composed of a compact mass of longitudinally directed fibres, all of which, as Déjerine has shown, arise in the cortex of the cerebrum and pursue an unbroken corticifugal course into and through the crusta of the crus cerebri. These fibres may be classified into two distinct sets, viz. cortico-pontine and pyramidal.

The **cortico-pontine fibres** possess this leading peculiarity: in their course downwards they are all arrested in the ventral part of the pons Varolii and end in fine terminal arborisations around the cells of the nucleus pontis. They come from certain well-defined areas of cerebral cortex, viz. (1) the cortex of the prefrontal part of the frontal lobe, and (2) the cortex of the middle portion of the temporal lobe. These tracts would appear to hold a very definite position within the crus. Thus it has been satisfactorily established that the *temporo-pontine strand* forms the outer or lateral fifth of the crusta, whilst the researches of Ferrier and Turner render it more than likely that the *fronto-pontine strand* holds a similar position in the inner or mesial part of the crusta.

The **pyramidal fibres** constitute the great motor tract from the cerebral cortex. They occupy a position corresponding to the middle three-fifths of the crusta. The pyramidal tract differs from the cortico-pontine strands in being carried downwards through the ventral part of the pons and on the ventral aspect of the medulla into the cord, which it enters in the form of the crossed and direct pyramidal tracts. On its way through the pons and medulla it sends fibres to the various motor nuclei in those sections of the brain-stem.

Deep Origin of the Cranial Nerves which arise within the Mesencephalon.

Two of the motor cranial nerves, viz. the oculo-motor and the trochlear nerves, as well as the mesencephalic root of the trigeminal nerve, obtain origin within the mesencephalon. The nuclei from which they spring are all situated within the gray matter of the Sylvian aqueduct.

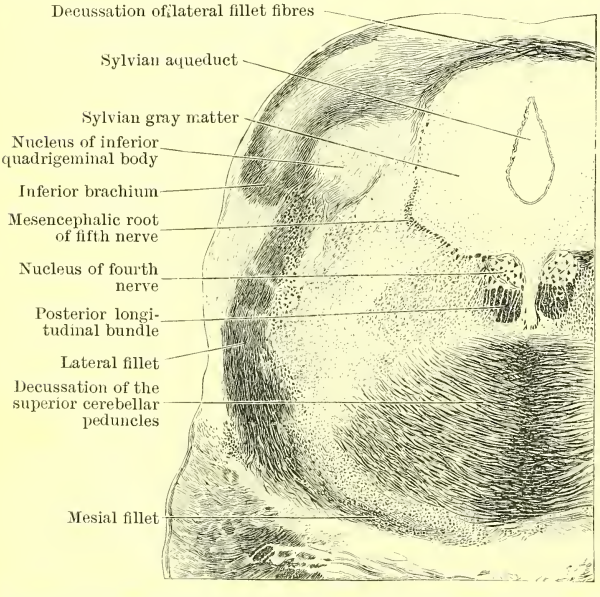


Fig. 436.—Section through the Inferior Quadrigeminal Body and the Tegmentum of the Mesencephalon at the Level of the Middle Part of the Nucleus of the Trochlear Nerve (Orang).

Mesencephalic Root of the Trigeminal Nerve (radix descendens).—The fibres of this root arise from a column of large, sparsely-arranged cells, which extends throughout the entire length of the mesencephalon. These cells lie in the outer part of the Sylvian gray matter, close to the tegmentum. The axons which emerge from the cells run downwards close to the outer surface of the Sylvian gray matter in the form of a small, gradually-increasing tract. In the lower part of the mesencephalon this tract assumes a crescentic outline, and ultimately comes to lie on the inner aspect of the superior cerebellar peduncle (Fig. 406, p. 504). The further course of the mesencephalic root of the fifth nerve through the upper part of the pons, to the point where it joins the emerging motor root of the trigeminal nerve, has already been traced (p. 526).

Trochlear or Fourth Nerve (nervus trochlearis).—The trochlear nerve supplies

the superior oblique muscle of the eyeball. It emerges from the brain, on its dorsal aspect, at the upper part of the superior medullary velum, immediately below the lower border of the inferior quadrigeminal body (Fig. 438, p 543). The nucleus from which it arises is a small oval mass of gray matter, placed in the ventral part of the Sylvian gray matter at the level of the upper part of the inferior quadrigeminal body. The close association of this nucleus with the posterior longitudinal bundle has already been alluded to. It is sunk deeply in a bay, which is hollowed out on the dorsal and inner aspect of that tract. The nerve has a course of some length within the mesencephalon. The axons of the cells leave the outer aspect of the nuclear mass, and curve backwards and outwards in the Sylvian gray matter until they reach the concave inner surface of the mesencephalic root of the trigeminal nerve. Here they are gathered together into one or two round bundles, which, bending sharply, turn downwards at a right angle and descend on the inner side of the trigeminal root. When the region below the inferior quadrigeminal body is reached, the nerve makes another sharp bend. This time it turns inwards, enters the upper end of the superior medullary velum, in which it decussates with its fellow of the opposite side. Having thus crossed the mesial plane, the trochlear nerve emerges at the inner border of the superior cerebellar peduncle. The course pursued by the fourth nerve within the Sylvian gray matter may be traced by examining in succession Fig. 437; Fig. 432, p. 537; Fig. 433, p. 538; and Fig. 407, p. 505.

Oculo-motor or Third Nerve (nervus oculo-motorius).—The oculo-motor nerve supplies the levator palpebræ superioris, all the ocular muscles, with the exception of the superior oblique and the external rectus, and also two muscles within the eyeball, viz. the sphincter iridis and the musculus ciliaris. The nucleus of origin is placed in the ventral part of the Sylvian gray matter subjacent to the superior quadrigeminal body (Fig. 431, p. 536). In length it measures from 5 to 6 mm. Its lower end is partially continuous with the nucleus of the trochlear nerve, whilst its upper end extends upwards for a short distance beyond the mesencephalon into the gray matter on the lateral wall of the third ventricle. Its relation to the posterior longitudinal bundle is even more intimate than that of the trochlear nucleus. It is closely applied to the dorsal and inner aspect of this strand; many of its cells occupy a position in the intervals between the nerve-bundles of the tract, and some even are seen on its ventral or tegmental aspect. The axons of the nuclear cells leave the nucleus in numerous bundles, which describe a series of curves as they proceed forwards through the posterior longitudinal bundle, the tegmentum, red nucleus, and inner margin of the substantia nigra, to finally emerge from the brain-stem along the bottom of the sulcus oculo-motorius on the inner aspect of the crus cerebri.

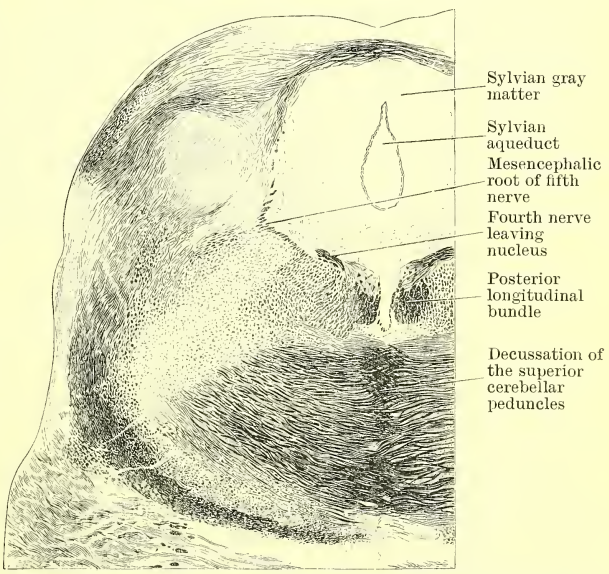


Fig. 437.—Section through the Inferior Quadrigeminal Body and the Tegmentum of the Mesencephalon at the Level of the Lower Part of the Nucleus of the Trochlear Nerve (Orang).

The cells of the oculo-motor nucleus are not uniformly distributed throughout it. They are grouped into several more or less distinct collections or clumps, some of which possess cells which differ in size and appearance from the others. These cell-clusters are very generally believed to possess a definite relation to the several branches of the nerve and the muscles which they supply. Perlia recognises no less than seven such cell-clusters in each nucleus, with a small

median nucleus placed accurately on the middle line, and from which fibres for both nerves spring. Whilst the majority of the fibres in the oculo-motor nerve arise from the cell-groups which lie on its own side of the mesial plane, it has been satisfactorily established that a certain proportion of its fibres are derived from the nucleus of the opposite side, thus forming a crossed connexion and giving rise to a median decussation. These crossed fibres are supposed by some to supply the internal rectus muscle; and we have seen that there is reason to believe that the part of the nucleus from which these fibres are derived stands in connexion through the posterior longitudinal fasciculus with the abducent or sixth nucleus from which proceeds the nerve of supply for the external rectus muscle. The harmonious action of the internal and external recti in producing the conjugate movements of the eyeballs is thus explained.

The oculo-motor nucleus is connected—(1) with the occipital part of the cerebral cortex by fibres which reach it through the optic radiation; (2) with the trochlear and abducent nuclei (and probably with other nuclei) by fibres which come to it through the posterior longitudinal bundle; (3) possibly with the facial nerve by fibres which pass out from it into the posterior longitudinal bundle (p. 538); (4) with the visual system by fibres which enter it from the cells of the superior quadrigeminal body.

Development of the Mesencephalon.

Even in the early embryo the mesencephalon constitutes the smallest section of the brain-tube, although the disproportion in size between it and the other primitive subdivisions of the brain is not nearly so marked as in the adult. Owing to the cephalic flexure, the mid-brain for a time occupies the highest part of the summit of the head. Later on it becomes completely covered over by the expanding cerebral hemispheres.

The corpora quadrigemina are derived from the alar laminæ of the lateral walls of the brain-tube, whilst the basal laminæ thicken and ultimately form the tegmenta and crustæ of the two crura cerebri. The original cavity of the mid-brain is retained as the aqueduct of Sylvius.

For a considerable time the cavity of the mesencephalon remains relatively large, and the lower part of its dorsal wall is carried downwards in the form of a diverticulum or recess, which overlaps the cerebellar plate. About this time, also, the dorsal wall shows a median fold or ridge. Both of these conditions are transitory. As the corpora quadrigemina take shape, the median ridge disappears and is replaced by the median longitudinal groove, which separates the quadrigeminal bodies. Only its lower part is retained, and this is represented by the frenulum veli of the adult brain. The diverticulum of the cavity gradually becomes reduced, and finally disappears as the aqueduct assumes form.

FORE-BRAIN.

Parts derived from the Diencephalon.

Under this heading we have to consider: (1) the **thalamus**; (2) the **epithalamus**, which comprises the pineal body and the habenular region; (3) the **metathalamus**, or the corpora geniculata; and (4) the **hypothalamus.**

The hypothalamus consists of two portions, viz. the **pars mammillaris hypothalami**, which comprises the corpus mammillare and the portion of the central gray matter which forms the floor of the third ventricle in its immediate vicinity; and the **pars optica hypothalami**, which embraces the tuber cinereum, the infundibulum, the pituitary body, and the lamina cinerea. Strictly speaking, the optic part of the hypothalamus does not belong to the diencephalon, but it is convenient to study the parts which it represents at this stage. It is also convenient to examine, at the same time, the **subthalamic tegmental region**, although a very considerable part of this is apparently developed in connexion with the mesencephalon.

The original cavity of that part of the brain-tube which forms the diencephalon is represented by the greater part of the third ventricle of the brain.

Optic Thalamus (thalamus).—The optic thalamus is the principal object in this section of the brain (Fig. 438). It is a large ovoid mass of gray matter, which lies obliquely across the path of the crus cerebri as it ascends into the cerebrum. The smaller anterior end of the thalamus lies close to the mesial plane, and is only separated from the corresponding part of the opposite side by a very narrow interval. The enlarged posterior ends of the two thalami are placed more widely apart, and in the interval between them the corpora quadrigemina are situated, As previously stated, the crusta of the crus cerebri, composed of corticifugal fibres

gradually inclines outwards as it is traced upwards, and thus it assumes a place on the outer aspect of the optic thalamus and passes into the internal capsule of the brain. The tegmental part of the crus, on the other hand, comes into relation with the under surface of the thalamus, and forms in this situation the **subthalamic tegmental region.** To a large extent the longitudinal fibres of the tegmentum are corticipetal. For the most part they enter the thalamus, and end within it in fine arborisations around the thalamic cells.

The two optic thalami, in their anterior two-thirds, lie close together on either side of a deep mesial cleft, which receives the name of the third ventricle of the brain. Each thalamus presents an anterior and a posterior extremity and four surfaces. The inferior and external surfaces are in apposition, and, indeed, directly connected with adjacent parts of the brain, and on this account it is only possible to study them by means of sections through the brain. The superior and internal surfaces are free.

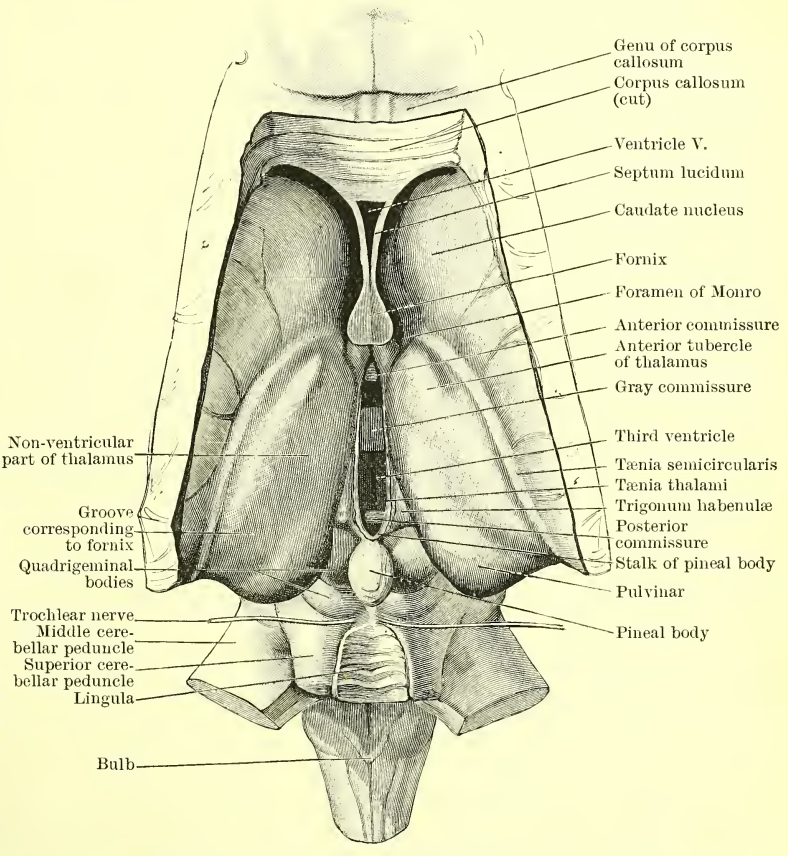


FIG. 438.—THE TWO OPTIC THALAMI (as seen from above).

The *external* or *lateral surface* of the thalamus is applied to a thick layer of white matter interposed between it and the lenticular nucleus, called the **internal capsule**, and composed of fibres passing both upwards towards and downwards from the cerebral cortex. A large proportion of these fibres descend to form the crusta or ventral part of the crus cerebri. From the entire extent of the external surface of the thalamus large numbers of fibres stream out and enter the internal capsule, to reach the cerebral cortex; over the same area other fibres which arise in the cortex of the cerebrum enter the thalamus. Both of these sets of fibres constitute what is termed the **thalamic radiation**, and by this the thalamus establishes a double connexion with the entire extent of the cerebral cortex. As the fibres leave and enter the thalamus they intersect each other at acute angles, and over the whole of the external surface of the ganglionic mass they form a very distinct reticulated zone or stratum, which is termed the **external medullary lamina.**

The *inferior* or *ventral surface* of the thalamus rests chiefly on the subthalamic tegmental region and the corpus mammillare. In front, however, as the tegmental substance gradually disappears, the thalamus comes to lie over the outer part of the tuber cinereum. From the subthalamic region many fibres enter the thalamus on its under aspect, whilst other fibres leave this surface of the thalamus to take part in the thalamic radiation.

The *superior* or *dorsal surface* of the thalamus is free. Externally it is bounded by a groove, which traverses the floor of the lateral ventricle of the brain and intervenes between the thalamus and the caudate nucleus. In this groove are placed a slender band of longitudinal fibres, termed the tænia semicularis, and in its fore-part the vein of the corpus striatum. Internally, the superior surface of the thalamus is separated from the internal or mesial surface in its anterior half by a sharp edge or prominent ledge of the ependyma of the third ventricle. This is termed the **tænia thalami**, and the ridge which it forms is accentuated by the fact that, subjacent to it, there lies a longitudinal strand of fibres called the **stria medullaris**. When these two structures, viz. the ependymal ridge and the subjacent tract, are traced backwards, they are seen to turn inwards and become continuous with the stalk or peduncle of the pineal body. Behind the portion of the tænia thalami which turns inwards towards the pineal body a small depressed triangular area, the **trigonum habenulæ**, situated in front of the superior quadrigeminal body, forms a very definite inner boundary for the hinder part of the superior surface of the thalamus.

The superior surface of the thalamus is slightly bulging or convex, and is of a whitish colour, owing to the presence of a thin superficial covering of nerve-fibres, termed the **stratum zonale**. It is divided into two areas by a faint oblique groove, which begins in front at the inner border, a short distance behind the anterior extremity of the thalamus, and extends outwards and backwards to the outer part of the hinder end. This groove corresponds to the outer edge of the fornix. The two areas which are thus mapped out are very differently related to the ventricles of the brain, and also to the parts which lie above the thalamus. The *outer area*, which includes the anterior extremity of the thalamus, forms a part of the floor of the lateral ventricle. It is covered with ependyma, overlapped by the choroid plexus of this ventricle, and lies immediately subjacent to the corpus callosum. Along the line of the groove the epithelial lining of the lateral ventricle is reflected over the choroid plexus of this cavity. The *inner area*, which includes the hinder end of the thalamus, intervenes between the lateral and third ventricles of the brain, and takes no part in the formation of the walls of either. It is covered by a fold of pia mater, termed the velum interpositum, above which is the fornix, and these two structures intervene between the thalamus and the corpus callosum.

The *anterior extremity* of the thalamus, called the **anterior tubercle** (tuberculum anterius thalami), forms a marked bulging. It projects into the lateral ventricle, behind and to the outer side of the free portion of the anterior pillar of the fornix. The foramen of Monro, a narrow aperture of communication between the lateral and third ventricles of the brain, is bounded in front by the anterior pillar of the fornix and behind by the anterior tubercle of the thalamus.

The *posterior extremity* of the thalamus is very prominent and forms a cushion-like projection, which overhangs the brachia of the corpora quadrigemina. This prominence is called the **pulvinar**. Another oval bulging on the hinder part of the thalamus receives the name of the **corpus geniculatum externum**. It is situated below, and to the outer side of, the pulvinar, and presents a very intimate connexion with the optic tract.

The *mesial surfaces* of the two thalami are placed close together, and are covered not only by the lining ependyma of the third ventricle, but also by a tolerably thick layer of gray matter, continuous below with the central gray substance which surrounds the aqueduct of Sylvius in the mesencephalon. A band of gray matter, termed the **gray** or **soft commissure** (commissura mollis), crosses the third ventricle and joins the inner surfaces of the two thalami together.

Intimate Structure and Connexions of the Optic Thalamus.—The upper surface of the thalamus is covered by the **stratum zonale**, a thin coating of white fibres derived to some extent from the optic tract, and probably also from the optic radiation. The inner surface has a thick coating of central gray matter, whilst intervening between the internal capsule and the outer surface is the **lamina medullaris externa**. The lower surface merges into the subthalamic region.

The gray matter of the optic thalamus is marked off into three very apparent parts—termed the anterior, the mesial, and the lateral thalamic nuclei—by a thin

vertical sheet of white matter, continuous with the stratum zonale, termed the **lamina medullaris interna**. The **lateral nucleus** (nucleus lateralis thalami) is by far the largest of the three. It is placed between the internal and the external medullary laminæ, and it stretches backwards beyond the mesial nucleus, and thus includes the whole of the pulvinar (Fig. 440). The **mesial nucleus** (nucleus medialis thalami) only reaches as far back as the habenular region. It is placed between the central gray matter of the third ventricle and the internal medullary lamina. The lateral nucleus is more extensively pervaded by fibres than the mesial nucleus. From the lateral nucleus by far the greatest number of the fibres which form the **radiatio thalami** pass, and these are seen crossing it in various directions towards the lamina medullaris externa. The **anterior nucleus** (nucleus anterior thalami) is the smallest of the three thalamic nuclei. It forms the prominent anterior tubercle, and is prolonged in a wedge-shaped manner, for a short distance, downwards and backwards between the anterior parts of the mesial and lateral nuclei. The internal medullary lamina splits into two parts and partially encloses the anterior nucleus. In connexion with its large cells a very conspicuous bundle of fibres, the **bundle of Vicq d'Azyr** (fasciculus thalamo-mammillaris), which arises in the corpus mammillare, comes to an end.

A diffuse gray mass imperfectly marked off from the under surface of the lateral nucleus receives the name of the *ventral nucleus*. Its lower part is composed of the **central nucleus of Luys** and the **nucleus arcuatus**. In section the former appears as a circular mass of gray matter, which comes into view immediately behind the point where the internal medullary lamina disappears. It would seem to be intimately connected with fibres which reach it from the red nucleus and from the posterior commissure. These fibres pass round it so as to mark it off from the rest of the thalamus, and in front of the nucleus many of them enter the internal medullary lamina. The **nucleus arcuatus** is a small semilunar mass of gray matter placed below and to the outer side of the central nucleus of Luys.

The **connexions of the thalamus** are of an extremely intricate kind. It would appear to be a ganglionic mass interposed between the tegmental corticipetal tracts and the cerebral cortex. In its hinder part, and through its stratum zonale, it also has important connexions with the optic tract. The corticipetal tegmental tracts, which enter it from below, will be noticed in connexion with the subthalamic region. Suffice it to say, for the present, that these fibres end in the midst of the thalamus in connexion with the thalamic cells. In addition to these, enormous numbers of fibres, arising within the thalamus as the axons of its cells, stream out from its outer and under surfaces to form the thalamic radiation. These **thalamo-cortical fibres** pass to every part of the cortex; and although there is no separation of them into distinct groups as they leave the thalamus, it is customary to regard them as constituting a frontal stalk, a parietal stalk, an occipital stalk, and a ventral stalk. But fibres from the cortex, **cortico-thalamic fibres**, likewise stream into the thalamus in large numbers, and end in fine arborisations around its cells. A double connexion with the cerebral cortex is thus established by the thalamus.

The **frontal stalk** of the thalamic radiation emerges from the anterior part of the lateral surface of the thalamus and passes through the anterior limb of the internal capsule, to reach the cortex of the frontal lobe. Many of these fibres end in the caudate and lenticular nuclei, between which they proceed. The **parietal stalk** issues from the lateral surface of the thalamus, and, passing through the internal capsule (and to some extent, also, through the lenticular nucleus and the external capsule), gains the cortex of the hinder part of the frontal lobe and of the parietal lobe. The **occipital stalk** emerges from the outer aspect of the pulvinar and constitutes the so-called optic radiation. These fibres sweep outwards and backwards round the outer side of the posterior horn of the lateral ventricle to gain the cortex of the occipital lobe. The **ventral stalk** streams out from the under aspect of the anterior part of the thalamus, in front of the subthalamic tegmental region and the corpus mammillare. Its fibres arise in both the mesial and lateral nuclei, and sweep downwards and outwards to reach the region below the lenticular nucleus. One very distinct band which lies dorsal to the other fibres (ansa lenticularis) enters the lenticular nucleus, whilst the remainder (ansa peduncularis) continue in an outward direction below the lenticular nucleus and gain the cortex of the temporal lobe and of the insula or island of Reil.

Flechsig divides the thalamo-cortical fibres of ordinary sensation into three sensory systems. These he has been able to distinguish by studying the order in which they assume their sheaths of myelin in the fœtus and infant.

Ferrier and Turner, by the degenerative method of investigation, corroborate Flechsig's results. They confirm the observation of Flechsig that, while thalamic fibres are distributed to

the several regions of the cerebral cortex to an almost equal extent, there is one district, viz. the frontal pole, to which the supply is scanty. Another very important result has been obtained by these authors. They have established the fact that many of the thalamic fibres cross the mesial plane in the corpus callosum, and thus gain the cortex of the opposite cerebral hemisphere. Hamilton's crossed callosal tract thus receives conformation.

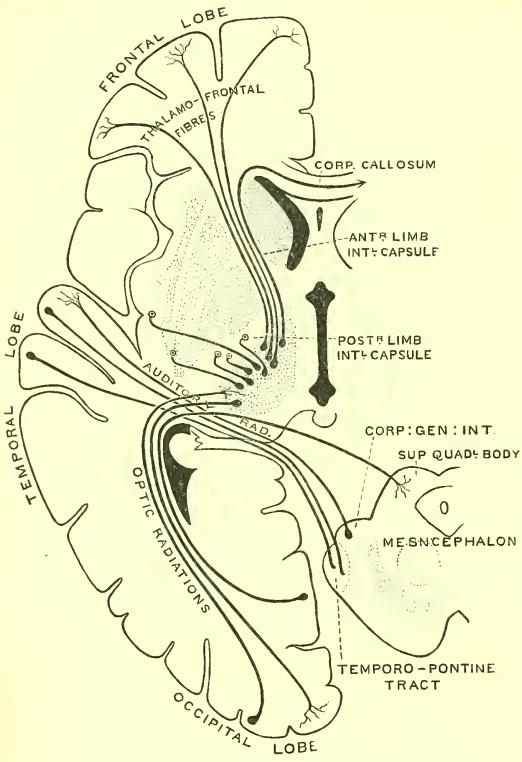


FIG. 439.—SCHEMA. Founded on the observations of Flechsig, and Ferrier and Turner.

Intimate Structure of the Corpus Geniculatum Externum. — Sections through the external geniculate body reveal the fact that it is composed of a series of alternately placed gray and white curved laminæ. This gives it a very characteristic appearance. The white laminæ are composed of fibres which enter the body from the optic tract and the optic radiation. The connexions of the geniculate bodies will be studied with the optic tract.

Subthalamic Tegmental Region. —The tegmental part of the crus cerebri is prolonged upwards and assumes a position below the hinder part of the thalamus. The **red nucleus** is a conspicuous object in sections through the lower part of this region (Fig. 440). It presents the same appearance as lower down in the mesencephalon, and, gradually diminishing, it disappears before the level of the corpus mammillare is reached. Carried up around it are the same longitudinal tracts of fibres which have been studied in relation to it in the tegmental part of the mesencephalon. Certain of these fibres, placed in immediate relation to the red nucleus, form a coating or capsule for it. This coating is partly derived from those fibres of the superior cerebellar peduncle which pass directly up into the thalamus and also partly from fibres which issue from the nucleus itself. The **mesial fillet**, also, which in the upper part of the mesencephalon is observed to take up a position on the lateral and dorsal aspect of the red nucleus, maintains a similar position in the subthalamic region. When the red nucleus comes to an end these various fibres are continued onwards and form, in the position previously occupied by the nucleus, a very evident and dense mass of fibres. The fibres of the mesial fillet, of the superior cerebellar peduncle, and of the red nucleus are prolonged upwards into the ventral part of the thalamus, where they end in connexion with the thalamic cells.

The **substantia nigra** is likewise carried into the subthalamic region, where it maintains its original position on the dorsal aspect of the crusta of the crus cerebri. As it is traced upwards, it is seen to gradually diminish in amount. It shrinks from within outwards, and finally disappears when the hinder part of the corpus mammillare is reached.

In coronal sections through the subthalamic region, the most conspicuous object which comes into view is the **corpus subthalamicum** or the **nucleus of Luys** (Fig. 440). It is a small mass of gray matter, shaped like a biconvex lens, which makes its appearance on the dorsal aspect of the crusta of the crus cerebri immediately to the outer side of the substantia nigra. At first it lies in an angle, which is formed by the meeting of the crusta and the internal capsule; but, rapidly enlarging in an inward direction, it takes the place of the diminishing substantia nigra on the dorsal surface of the crusta at the level of the lower part of the corpus mammillare. The corpus subthalamicum is rendered all the more evident by the fact that it is

sharply defined by a thin capsule of white fibres. On its mesial aspect these fibres proceed inwards and form a very evident decussation across the middle line in the floor of the third ventricle, immediately above the hinder ends of the corpora mammillaria.

The corpus subthalamicum, in the fresh condition, presents a brownish colour, partly from the fact that its cells are pigmented, and partly also on account of the numerous capillary blood-vessels which pervade its substance.

Pineal Body (corpus pineale).—This is a small, dark, reddish body, about the size of a cherry-stone and shaped after the fashion of a fir-cone. Placed between the hinder ends of the two thalami, it occupies the depression on the dorsal aspect of the mesencephalon, which intervenes between the two superior quadrigeminal bodies. Its base, which is directed upwards, is attached by a hollow stalk or peduncle. This stalk is separated into a dorsal and a ventral part by the prolongation backwards into it of a small pointed recess of the cavity of the third ventricle. The dorsal part of the stalk curves outwards and forwards, and on each optic thalamus becomes continuous with the tænia thalami and the subjacent stria medullaris; the ventral part is folded round a narrow but conspicuous cord-like band of white matter, which crosses the mesial plane immediately above the base of the pineal body and receives the name of the **posterior commissure** of the cerebrum (Fig. 438, p. 543).

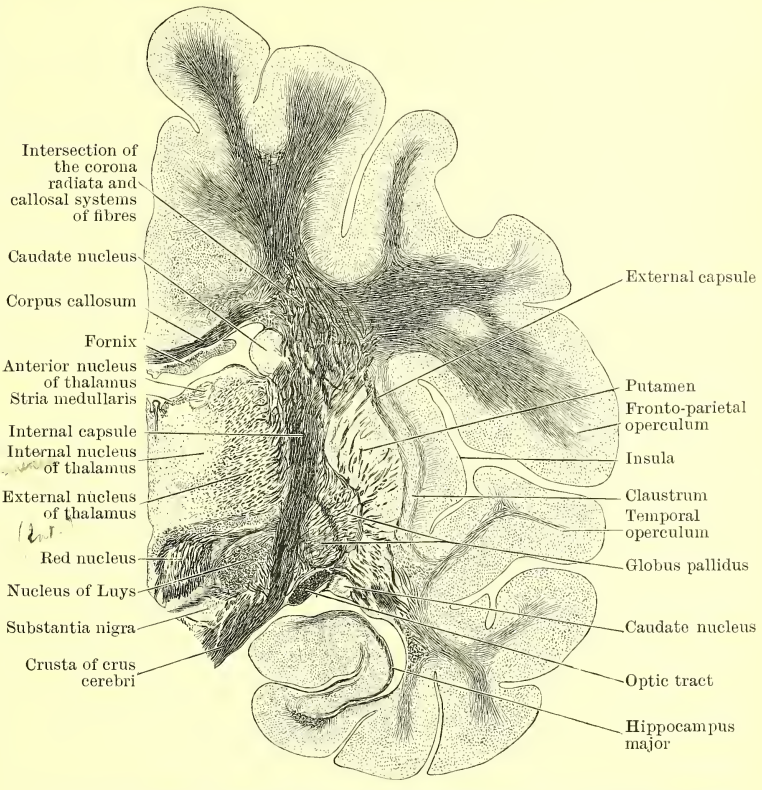


Fig. 440.—Coronal Section through the Cerebrum of an Orang passing through the Subthalamic Tegmental Region.

The pineal body is not composed of nervous elements. The only nerves in its midst are the sympathetic filaments which enter it, with its blood-vessels. It is composed of spherical and tubular follicles, filled with epithelial cells, and containing a variable amount of gritty, calcareous matter.

The pineal body is a rudimentary structure, but in certain vertebrates it attains a much higher degree of development than in man. In the lizard, blind-worm, etc., it is present in the form of the so-called pineal eye. In structure it resembles, in these animals, an invertebrate eye, and it possesses a long stalk, in which nerve-fibres are developed. Further, it is carried through an aperture in the cranial wall, and consequently lies close to the surface on the dorsum of the head between the parietal bones.

Trigonum Habenulæ.—The small, triangular, depressed area which receives this name is placed immediately in front of the superior quadrigeminal body in the interval between the peduncle of the pineal body and the hinder end of the thalamus (Fig. 438, p. 543). It marks the position of an important collection of nerve-cells, which constitute the **ganglion habenulæ**. The axons of these cells are collected on the ventral aspect of the ganglion into a bundle, called the **fasciculus retroflexus**, which takes a curved course downwards and forwards in the tegmentum of the

mesencephalon. The fasciculus retroflexus lies close to the inner side of the red nucleus, and finally comes to an end in a group of cells termed the **ganglion interpedunculare**, situated in the lower part of the locus perforatus posticus (see p. 539).

The ganglion habenulæ is likewise intimately connected with the stria medullaris and the dorsal part of the stalk of the pineal body.

As previously stated, the **stria medullaris**—a very evident band of white matter—lies on the optic thalamus, subjacent to the ependymal ridge termed the tænia thalami. When traced backwards, many of the fibres of the stria medullaris are observed to end amongst the cells of the ganglion habenulæ, whilst others are continued past the ganglion to enter the peduncle of the pineal body, and, through it, to reach the ganglion habenulæ of the opposite side, in connexion with the cells of which they terminate. The stria medullaris, therefore, ends partly in the ganglion habenulæ of its own side and partly in the corresponding ganglion of the opposite side. The decussation of fibres across the middle line forms the dorsal part of the pineal stalk or peduncle, and is frequently termed the **commissura habenularum**.

When the stria medullaris is traced in the opposite direction, it is noticed to split into a dorsal and ventral part near the anterior pillar of the fornix. The *dorsal part* turns abruptly upwards, and, joining the fornix, is carried in it to the hippocampus major or cornu ammonis from cells in which its fibres take origin. The *ventral part* turns downwards and appears to spring from a collection of cells in the gray matter on the base of the brain close to the optic chiasma. The stria medullaris is believed to form a part of the olfactory apparatus.

Commissura Posterior.—The posterior commissure is a slender band of white matter, which crosses the middle line under cover of the stalk of the pineal body and overlies the entrance of the aqueduct of Sylvius into the third ventricle. The fibres which enter into the formation of the posterior commissure are believed to arise in a special nucleus, which is placed in the central gray matter immediately above the oculo-motor nucleus. They decussate with each other across the mesial plane and thus the commissure is formed. The other connexions of this little band are not satisfactorily established, but Held believes that some of its ventral fibres pass downwards into the posterior longitudinal bundle.

Locus Perforatus Posticus (substantia perforata posterior).—This has already been described on p. 475. Some delicate bands of white matter, termed the **tænia pontis**, may frequently be seen emerging from the gray matter of this region; they then curve round the crura cerebri in close relation to the upper border of the pons, into which they ultimately sink (Fig. 390, p. 484).

Corpora Mammillaria.—The corpora mammillaria are two round white bodies, each about the size of a pea, which lie side by side in the interpeduncular space on the base of the brain, immediately in front of the locus perforatus posticus.

Each corpus mammillare is coated on the outside by white matter derived from the anterior pillar of the fornix, and contains, in its interior, a composite gray nucleus with numerous nerve-cells. Several important strands of fibres are connected with the corpus mammillare: (1) The **anterior pillar of the fornix** curves downwards in the lateral wall of the third ventricle to reach the corpus mammillare, and its fibres end amidst the cells of that body. (2) A bundle of fibres, called the **bundle of Vicq d'Azyr**, which at first sight appears to be continuous with the anterior pillar of the fornix, takes origin in its midst and extends upwards into the optic thalamus, to end in fine arborisations around the large cells in the anterior thalamic nucleus. (3) Another bundle of fibres, the **pedunculus corporis mammillaris**, takes form within the corpus mammillare and extends downwards in the gray matter of the floor of the third ventricle, to reach the tegmentum of the mesencephalon. The ultimate destination of these fibres is doubtful.

Tuber Cinereum and Infundibulum.—The tuber cinereum is a small, slightly prominent field of gray matter, which occupies the anterior part of the interpeduncular space between the corpora mammillaria behind and the optic chiasma in front. From its fore-part the **infundibulum**, or stalk of the pituitary body, projects downwards and connects that body with the base of the brain. In its

upper part the infundibulum is hollow, a small, funnel-shaped diverticulum of the cavity of the third ventricle being prolonged downwards into it.

Pituitary Body (hypophysis).—This is a small oval structure, flattened from above downwards, and with its long axis directed transversely, which occupies the pituitary fossa in the floor of the cranium. It is composed of two lobes—a large anterior lobe and a smaller posterior lobe, which are closely applied the one to the other. The infundibulum, which extends downwards from the tuber cinereum, is attached to the posterior lobe.

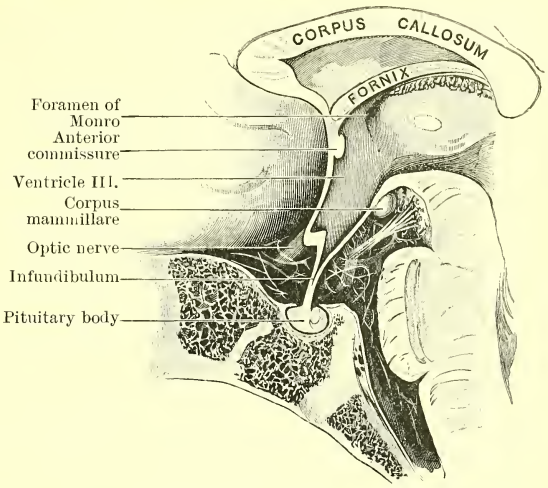


Fig. 441.—Mesial Section through the Pituitary Region in a Child of Twelve Months old.

In this section, as well as in the section figured in Fig. 442, the infundibulum has the appearance of being attached to the anterior lobe. This is due to the way in which the larger anterior lobe grows backwards so as to embrace the smaller posterior lobe. The latter is, as it were, accommodated in a hollow in the hinder aspect of the anterior lobe.

From a photograph by Professor Symington.

The infundibulum and posterior lobe of the pituitary body are developed in the form of a hollow diverticulum, which grows downwards from the floor of that part of the embryonic brain which afterwards forms the third ventricle. The original cavity of this diverticulum becomes obliterated, except in the upper part of the infundibulum. In structure, the posterior lobe of the pituitary body shows little trace of its origin from the wall of the brain-tube. It is chiefly composed of connective tissue and blood-vessels, with branched cells scattered throughout it.

The anterior lobe has quite a different origin, and may be regarded as the functional part of the pituitary body. It is derived from a tubular diverticulum, which grows upwards from the primitive buccal cavity or stomodæum. Its connexion with the latter (canalis cranio-pharyngeus) is in the course of time cut off, and the diverticulum becomes encased within the cranial cavity in intimate association with the cerebral portion of the organ. Structurally, it consists of tubules or alveoli, lined by epithelial cells and surrounded by capillary vessels. Its structure is in some respects not unlike that of the parathyroid bodies. In giants, and in cases of acromegaly, the pituitary body is usually greatly enlarged.

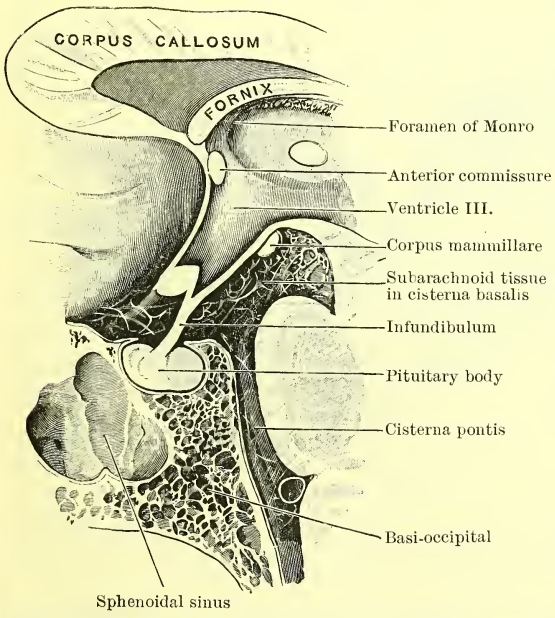


Fig. 442.—Mesial Section through the Pituitary Region in the Adult.

Lamina Cinerea.—This is a thin, delicate lamina which may be seen on the basal aspect of the brain, stretching from the upper aspect of the optic chiasma in an upward direction to become connected with the rostrum of the corpus callosum.

Anterior Commissure of the Cerebrum.—In the anterior part of the cleft, between the two optic thalami and immediately in front of the anterior pillars of the fornix, a round bundle of fibres crosses the mesial plane. This is the anterior commissure. It is much larger than the posterior commissure.

Third Ventricle (ventriculus tertius). — This is the narrow cleft which separates the two optic thalami. Its depth rapidly increases from behind forwards, and it may be said to extend from the pineal body behind to the lamina cinerea in front. Its *floor* is formed by the structures already studied within the area of the interpeduncular space on the base of the brain, viz. the tuber cinereum, the corpora mammillaria, the gray matter of the locus perforatus posticus, and also to some extent behind this by the tegmenta of the crura cerebri. It is interesting to note that the central gray matter which surrounds the Sylvian aqueduct is directly continuous with the gray matter of the locus perforatus posticus and tuber cinereum, and in this way it comes to the surface in the base of the brain. The optic chiasma crosses the floor in front and marks the place where the latter becomes continuous with the anterior wall of the cavity. The *front wall* of the third ventricle is formed by the lamina cinerea, which extends upwards from the optic chiasma. The anterior commissure, as it crosses from one side to the other, projects into the ventricle, but of course it is excluded from the cavity by the ventricular epithelial lining. It may be taken as indicating the place where the roof joins the anterior wall. The *roof* of the third ventricle is formed by a thin epithelial layer, continuous with the thin epithelial lining of the cavity, which stretches across the mesial plane from one tænia thalami to the other. Applied to the upper surface of the epithelial roof is the fold of pia mater, termed the velum interpositum, and the roof is invaginated into the cavity along its whole length by two delicate choroid plexuses, which hang down from the under surface of this fold. When the velum interpositum is removed the thin epithelial roof is torn away with it, leaving only the lines of attachment in the shape of the tænia thalami.

The *lateral wall* of the third ventricle is formed for the greater part of its extent by the inner surface of the optic thalamus, covered by a thick layer of

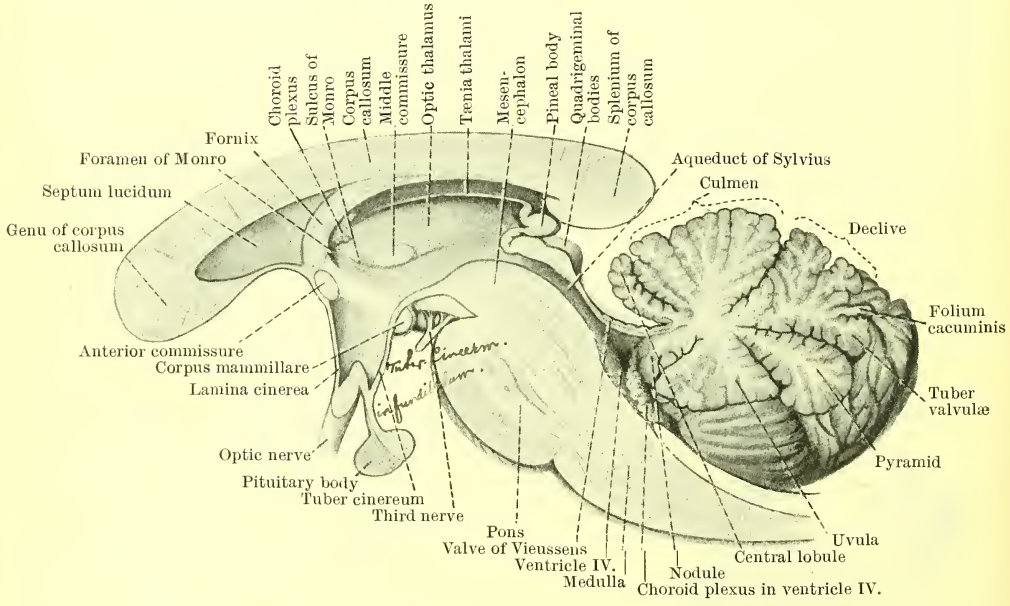


FIG. 443.—MESIAL SECTION THROUGH THE CORPUS CALLOSUM, DIENCEPHALON, ETC.
Shows the third and fourth ventricles connected by the aqueduct of Sylvius.

central gray matter continuous with the Sylvian gray matter of the mesencephalon. A little in front of the middle of the ventricle the cavity is crossed by the **middle** or **soft commissure**, which connects the thalami with each other, and in front of this the anterior pillar of the fornix is seen curving downwards and backwards in the lateral wall. At first the bulging which it forms is distinctly prominent, but it gradually subsides as the strand, on its way to end in the corpus mammillare, becomes more and more sunk in the gray matter on the side of the ventricle.

The third ventricle communicates with both of the lateral ventricles, and also with the fourth ventricle. The **aqueduct of Sylvius**, the narrow channel which tunnels the mesencephalon, brings it into communication with the fourth ventricle. The opening of this aqueduct is placed at the posterior part of the floor of the third ventricle, immediately below the posterior commissure. The **foramina of Monro**

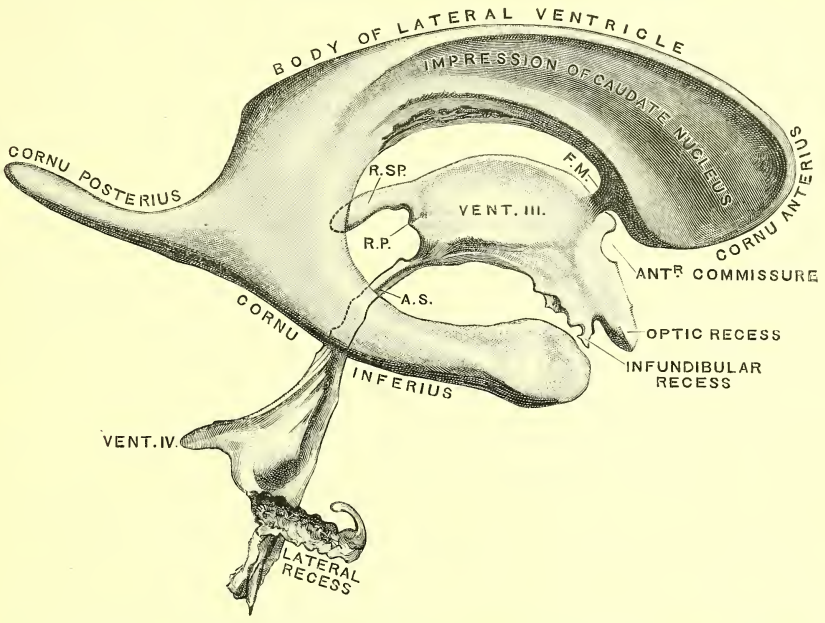


FIG. 444.—PROFILE VIEW OF A CAST OF THE VENTRICLES OF THE BRAIN (from Retzius).

R.SP. Recessus suprapinealis.
R.P. Recessus pinealis.
A.S. Aqueduct of Sylvius.
F.M. Foramen of Monro.

bring it into communication with the lateral ventricles. These apertures are placed at the upper and fore parts of the lateral walls, and lead outwards and slightly upwards between the most prominent parts of the anterior pillars of the fornix and the anterior tubercles of the optic thalami. They are just large enough to admit a crow-quill, and through these passages the epithelial lining of the three ventricles becomes continuous. From the foramen of Monro a distinct groove on the lateral wall of the ventricle leads backwards towards the mouth of the Sylvian aqueduct. It is termed the **sulcus of Monro**, and is of interest, inasmuch as it is considered by His to represent in the adult brain the furrow which divides the lateral wall of the embryonic brain-tube into an alar and a basal lamina.

The outline of the third ventricle, when viewed from the side in a mesial section through the brain, or as it is exhibited in a plaster cast of the ventricular system of the brain, is seen to be very irregular (Fig 444). It presents several diverticula or recesses. Thus, in the fore-part of the floor there is a funnel-shaped pit or recess, leading down through the tuber cinereum into the infundibulum of the pituitary body. Another recess, the *recessus opticus*, leads forwards immediately in front of this, above the optic chiasma. Posteriorly two diverticula are present. One, the *recessus pinealis*, passes backwards above the posterior commissure and the mouth of the Sylvian aqueduct for a short distance into the stalk of the pineal body. The second is placed above this and is carried backwards for a greater distance. It is a diverticulum of the epithelial roof, and, therefore, is difficult to demonstrate. It is termed the *recessus suprapinealis*

CEREBRAL CONNEXIONS OF THE OPTIC TRACT.

One nerve, the optic nerve or the nerve of sight, is connected with this section of the brain. At the optic chiasma the optic nerves of the two sides are joined together and a partial decussation of fibres takes place. The fibres which arise in the mesial half of each retina cross the mesial plane and join the optic tract of the

opposite side. The optic tract proceeds backwards round the crus cerebri, and in the neighbourhood of the corpora geniculata divides into two roots, viz. a lateral and a mesial (p. 532).

Mesial Root of the Optic Tract—Commissure of Gudden.—The mesial root of the optic tract disappears under cover of the corpus geniculatum internum and a large proportion of its fibres arise or end in this nuclear body. As to the connexions of the other fibres, we possess at present no precise information. The mesial root, although it is composed of fibres which run in the optic tract, has absolutely nothing to do with the optic nerve. These fibres, when traced forwards, cross the mesial plane in the posterior angle of the optic chiasma and are carried backwards in the opposite optic tract, to form on that side its mesial root. The fibres, therefore, are commissural, and constitute a bond of union, called the **commissure of Gudden**, between the internal geniculate bodies.

Lateral Root of the Optic Tract.—The lateral or true visual root of the optic tract is composed of fibres which come—(1) from the lateral half of the retina of its own side; and (2) from the mesial half of the retina of the opposite side, and which have crossed the mesial plane in the optic chiasma. But in addition to the afferent retinal fibres there are a certain number of efferent fibres in the optic tract, fibres which take their origin in the brain and end in the retina. These are distinguished from the afferent retinal fibres by their exceeding fineness.

The fibres of the lateral root of the optic tract end in the superior quadrigeminal body, in the external geniculate body, and in the pulvinar of the optic thalamus. The fibres to the **superior quadrigeminal body** reach it through the superior brachium (p. 435), and for the most part spread out on its surface in the stratum zonale before they sink into its substance, to end in terminal arborisations around its cells. The **corpus geniculatum externum** receives the largest contribution of fibres from the lateral root of the optic tract. These partly sink into its interior and partly spread out over its surface. The former enter into the construction of the curved lamellæ of white matter which traverse this nuclear mass, and to a large extent end in the gray matter which intervenes between these lamellæ. The deep fibres which are not exhausted in this way proceed onwards through the external geniculate body and enter the pulvinar. Of the superficial fibres which spread over the surface of the external geniculate body some dip into its substance and end there, but the majority are carried over it and enter the stratum zonale of the pulvinar. The fibres of the lateral root of the optic tract, which end in the **pulvinar**, therefore reach their destination by passing either over or through the external geniculate body.

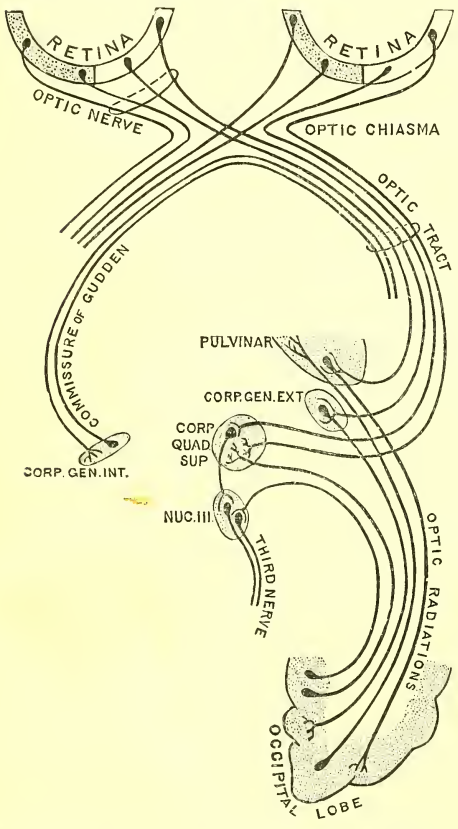


FIG. 445.—DIAGRAM OF THE CENTRAL CONNEXIONS OF THE OPTIC NERVE AND OPTIC TRACT.

Cortical Connexions of the Optic Nerve.—The superior quadrigeminal body, the external geniculate body, and the pulvinar constitute the lower visual centres or terminal nuclei of the visual part of the optic tract. The higher visual centre is placed in the cortex of the occipital lobe of the cerebral hemisphere, and the connexions between this and the lower centres are established by a large strand of fibres which runs in the central white matter of the hinder part of the cerebral hemisphere, and which

constitutes the **optic radiation**. The optic radiation is composed both of corticipetal and corticifugal fibres. The former arise as the axons of the cells in the external geniculate body and the pulvinar, around which the retinal fibres end, and they terminate in the cortex of the occipital lobe. The corticifugal fibres take origin in the cortex of the occipital lobe and end in the pulvinar and superior quadrigeminal body (Ferrier and Turner). Thus constituted, the optic radiation forms a conspicuous strand (Figs. 462, p. 576; 465, p. 579; 473, p. 592), which, reaching the retrolenticular part of the internal capsule, sweeps backwards into the occipital lobe of the cerebral hemisphere on the outer side of the posterior horn of the lateral ventricle. Its connexions will be studied more fully at a later stage.

Flechsig does not believe that the pulvinar is an internode interposed in the path of the optic nerve as it proceeds towards the visual area of the cerebral cortex. He states that he has not been able to convince himself that any fibres of the optic tract end in the optic thalamus.

Other Connexions of the Lower Group of Visual Centres.—(1) The nuclei of the nerves which supply the muscles which move the eyeball would appear to stand in intimate connexion with the lower group of visual centres. Most probably this connexion is established through the posterior longitudinal bundle. As previously stated, Held believes that axons of certain of the cells of the superior quadrigeminal body enter this tract. (2) Through the mesial fillet, the superior quadrigeminal body is connected with the medulla and cord.

THE PARTS DERIVED FROM THE TELENCEPHALON.

Cerebral Hemispheres.

The cerebral hemispheres form the largest part of the fully-developed brain. When viewed from above they form an ovoid mass, the broadest end of which is directed backwards, and the longest transverse diameter of which will be found in the vicinity of the parts which lie subjacent to the parietal eminences of the cranium. The massive rounded character of the anterior or frontal end of each cerebral hemisphere constitutes a leading human characteristic; but the hinder or occipital end is narrow and pointed, and is directed somewhat downwards. The two cerebral hemispheres are separated from each other by a deep mesial cleft, termed the great longitudinal fissure.

Great Longitudinal Fissure (fissura longitudinalis cerebri).—In front and behind the great longitudinal fissure passes from the dorsal to the ventral aspect of the cerebral hemispheres, so as to separate them completely from each other. In its middle part, however, the fissure is interrupted and floored by the corpus callosum, a white commissural band, which passes between the hemispheres and connects them together. The upper surface of the corpus callosum can be displayed by gently drawing asunder the contiguous mesial surfaces of the cerebral hemispheres. The great longitudinal fissure is occupied by a mesial fold of dura mater, termed the falx cerebri, which partially subdivides the part of the cranial cavity allotted to the cerebrum into a right and left chamber.

External Configuration of each Cerebral Hemisphere.—Each cerebral hemisphere presents an external, an internal, and an inferior surface. The *external surface* is convex and is adapted accurately to the deep surface of the cranial vault. The *internal* or *mesial surface* is flat and perpendicular, and bounds the great longitudinal fissure. In great part it is in contact with the falx cerebri; and where that partition is deficient, it is applied to the corresponding portion of the internal surface of the opposite hemisphere. The *inferior surface* is irregular and is adapted to the anterior and middle cranial fossæ of the cranial floor and, behind these, to the upper surface of the tentorium cerebelli. Traversing this surface in a transverse direction, nearer the anterior end of the hemisphere than the posterior end, is the stem of the Sylvian fissure. This deep cleft divides the inferior surface into an anterior or *orbital area*, which rests on the orbital plate of the frontal bone, and is consequently concave from side to side, and a more extensive posterior or *tentorial area*, which lies on the floor of the lateral part of the middle cranial fossa and upon the upper surface of the tentorium cerebelli. This surface is arched from before backwards, and looks inwards as well as downwards. In its hinder two-thirds it lies above the cerebellum, from which it is separated by the tentorium cerebelli.

The borders which intervene between these surfaces are the supero-mesial, the superciliary, the infero-lateral, and the internal occipital. The *supero-mesial border*, convex from before backwards, intervenes between the convex external surface and the flat internal surface of the hemisphere. The *superciliary border* is highly arched and separates the orbital surface from the external surface. The *infero-lateral border* marks off the tentorial surface from the external surface. The *internal occipital border* can only be seen in cases where the brain has been hardened *in situ* and faithfully retains the natural form. It extends from the posterior end of the hemisphere towards the hinder extremity of the corpus callosum, and intervenes between the mesial and tentorial surfaces. It is the border which lies along the straight blood sinus, and it therefore occupies the angle which is formed by the attachment of the posterior part of the falx cerebri to the upper surface of the tentorium cerebelli.

The most projecting part of the anterior end of the cerebral hemisphere is called the **frontal pole**, whilst the most projecting part of the hinder end is termed the **occipital pole**. On the under surface of the hemisphere the prominent point of cerebral substance which extends forwards below the Sylvian fissure receives the name of the **temporal pole**. In a well-hardened brain a broad groove is usually present on the inner and lower aspect of the occipital pole of the right hemisphere. This corresponds to the commencement of the right lateral venous sinus. A less distinct groove on the occipital pole of the left hemisphere frequently indicates the commencement of the left lateral sinus. On the tentorial surface, a short distance behind the temporal pole, a well-marked depression is always visible. This corresponds to the elevation on the anterior surface of the petrous portion of the temporal bone over the superior semicircular canal.

Cerebral Gyri and Sulci.—The surface of the cerebral hemispheres is rendered highly irregular by the presence of convolutions or gyri, separated from each other by intervening furrows of very varying depth, termed sulci or fissures. The surface pattern which is presented by these gyri and sulci is, in its general features, the same in all normal human brains; but when the comparison is pushed into detail many differences become manifest, not only in the brains of different individuals, but also in the two cerebral hemispheres of the same individual.

There are two varieties of furrows, viz. complete and incomplete. The **complete fissures** are few in number, and are formed by inwardly-directed infoldings involving the entire thickness of the cerebral wall. They consequently show in the interior of the cerebral cavity or lateral ventricle in the form of internal elevations on its wall. The complete fissures are the following: (1) the dentate or hippocampal fissure; (2) the anterior part of the calcarine fissure; and (3) a portion of the collateral fissure. The **incomplete fissures** are merely surface furrows of varying depth, which do not produce any effect on the inner surface of the ventricular wall.

General Structure of the Cerebral Hemispheres.—Each cerebral hemisphere is composed of an outside coating of gray matter, spread in a continuous and uninterrupted layer over its surface, and an internal mass of white matter, which forms a considerable part of the immediate wall of the ventricular cavity. The gray coating is termed the **cerebral cortex**, and the internal white matter is called the **medullary centre**. Each convolution shows a corresponding structure. On transverse section it is seen to present an external covering of gray cortex, supported by a central core of white matter.

But, in addition to the gray matter on the outside, there are certain large deposits of gray matter embedded in the basal part of each cerebral hemisphere. These cerebral nuclei constitute the **corpus striatum**, and, although to some extent isolated from the gray matter on the surface, it can be easily shown that at certain points they are directly continuous with it.

By means of the convolutions and sulci, the gray matter on the surface of the hemisphere is enormously increased in quantity without unduly adding to the bulk of the organ; and, further, the vascular pia mater, which dips into every fissure, is increased in extent to a like degree. Opportunity is, therefore, afforded to the cortical vessels of breaking up into twigs of exceeding fineness before they enter the

substance of the hemisphere. The distribution of blood to the gray cortex is, in this way, equalised and rendered uniform.

Cerebral Lobes and Interlobar Fissures.—Certain of the fissures which traverse the surface of the cerebrum are more or less arbitrarily chosen for subdividing the surface into districts or areas, which are termed lobes. These fissures are termed **interlobar**, and are the following: (1) the fissure of Sylvius; (2) the fissure of Rolando; (3) the parieto-occipital; (4) the calloso-marginal; (5) the collateral; and (6) the limiting sulcus of Reil.

The lobes which are mapped out by these fissures are: (1) the frontal; (2) the parietal; (3) the occipital; (4) the temporal; (5) the insula, or the island of Reil; (6) the limbic. To these may be added a seventh lobe, in no way related to the interlobar fissures, viz. the olfactory lobe. With the exception of the occipital and olfactory lobes and the insula, this subdivision of the hemisphere possesses little morphological value, and is chiefly adopted for topographical purposes.

Fissure of Sylvius (fissura cerebri lateralis).—This is the most conspicuous

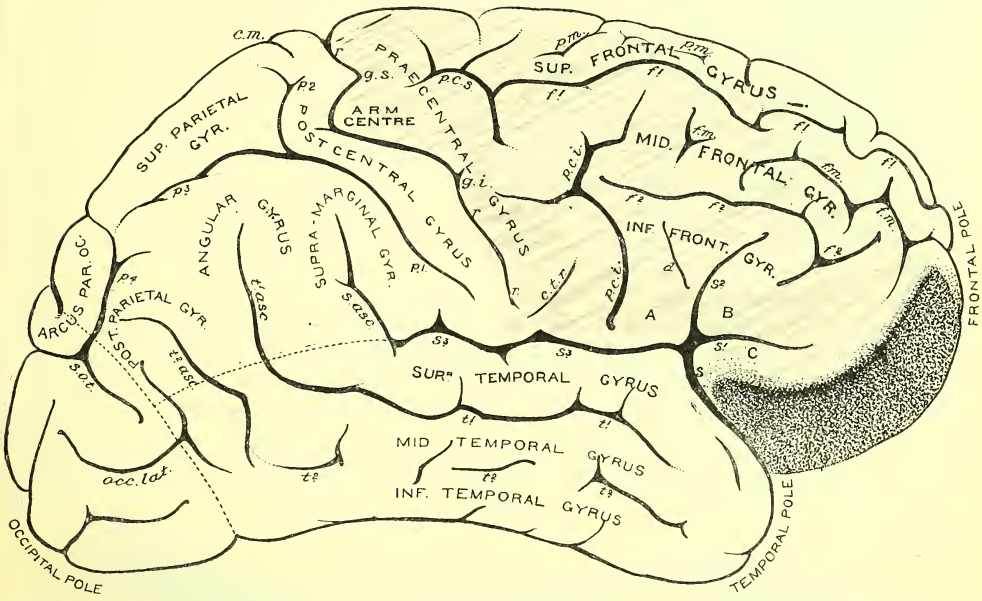


FIG. 446.—GYRI AND SULCI, on the outer surface of the cerebral hemisphere.

f^1. Sulcus frontalis superior.	r. Fissure of Rolando.
f^2. Sulcus frontalis inferior.	g.s. Superior genu.
f.m. Sulcus frontalis medius.	g.i. Inferior genu.
p.m. Sulcus paramedialis.	d. Sulcus diagonalis.
A. Pars basilaris.	t^1. Superior temporal sulcus (parallel sulcus).
B. Pars triangularis.	t^2. Inferior temporal sulcus.
C. Pars orbitalis.	p^1. Inferior postcentral sulcus.
S. Sylvian fissure.	p^2. Superior postcentral sulcus.
s^1. Anterior horizontal limb (Sylvian fissure).	p^3. Ramus horizontalis.
s^2. Ascending limb (Sylvian fissure).	p^4. Ramus occipitalis.
s^3. Posterior horizontal limb (Sylvian fissure).	s.o.t. Sulcus occipitalis transversus.
s.asc. Ascending terminal part of the posterior horizontal limb of the Sylvian fissure.	occ. lat. Sulcus occipitalis lateralis (the sulcus lunatus of Elliot Smith).
p.c.i. Inferior præcentral sulcus.	c.m. Calloso-marginal sulcus.
p.c.s. Superior præcentral sulcus.	c.t.r. Inferior transverse furrow.

fissure on the surface of the cerebral hemisphere. It is composed of a short main stem, from the outer extremity of which three branches or limbs radiate. The **stem** of the Sylvian fissure is placed on the inferior surface of the hemisphere. It begins at the locus perforatus anticus in a depression termed the **vallecula Sylvii**. From this it passes horizontally outwards, forming a deep cleft between the temporal pole and the orbital surface of the frontal lobe. Appearing on the outer surface of the hemisphere at a point called the **Sylvian point**, the Sylvian fissure immediately divides into three radiating branches. These are: (1) the

ramus horizontalis posterior; (2) the ramus horizontalis anterior; (3) the ramus anterior ascendens.

The **posterior horizontal limb** is the longest and best marked of the three limbs. It extends backwards, with a slight inclination upwards on the outer surface of the hemisphere for a distance which may vary from about two to three inches. It intervenes between the frontal and parietal lobes which lie above it and the temporal lobe which lies below it, and it finally ends in the region subjacent to the parietal eminence of the cranial wall by turning upwards into the parietal lobe in the form of an *ascending terminal piece.*

The **anterior horizontal limb** extends horizontally forwards in the frontal lobe for a distance of about three-quarters of an inch immediately above and parallel to the posterior part of the superciliary margin of the hemisphere.

The **ascending limb** proceeds upwards, with a slight inclination forwards, into the lower part of the outer surface of the frontal lobe for a distance of about an inch. In many cases the two anterior limbs spring from a common stem of greater or less length, and not infrequently both are replaced by a single anterior limb.

Limiting Sulcus of Reil (sulcus circularis Reilii).—If the lips of the posterior horizontal limb of the Sylvian fissure be widely pulled asunder from each other, the insula or island of Reil will be seen at the bottom. The insular district of the cortex is completely hidden from view when the Sylvian fissure is closed by overlapping portions of the cerebral hemisphere, and, when brought into view in the manner indicated, it is observed to present a triangular outline and to be surrounded by a limiting sulcus, of which three parts may be recognised, viz.: an *upper part,* bounding it above and separating it from the parietal and frontal lobes; a *lower part,* marking it off below from the temporal lobe; and an *anterior part,* separating it in front from the frontal lobe.

Opercula Insulæ.—The overlapping portions of the cerebral substance which cover over the insula are termed the insular opercula, and they form, by the apposition of their margins, the three limbs of the Sylvian fissure. The opercula are four in number and are named: (1) temporal; (2) fronto-parietal; (3) frontal; and (4) orbital. The limbs of the Sylvian fissure cut right through between the different opercula and extend from the exposed surface of the hemisphere to the submerged surface of the insula, and, in this manner, separate the opercula from each other.

The **temporal operculum** extends upwards over the insula from the temporal lobe, and its upper margin forms the lower lip of the posterior horizontal limb of the Sylvian fissure.

The **fronto-parietal operculum** is carried downwards from the parietal and frontal regions over the insula, and its lower margin, meeting the temporal operculum, forms the upper lip of the posterior limb of the Sylvian fissure.

The **frontal operculum** is the small triangular piece of cerebral substance which intervenes between the ascending and anterior horizontal limbs of the Sylvian fissure. It covers over a small part of the anterior portion of the insula, and is sometimes termed the **pars triangularis.**

The **orbital operculum** is, for the most part, on the under surface of the hemisphere. It lies below and to the inner side of the anterior horizontal limb of the Sylvian fissure, and proceeds backwards from the orbital aspect of the frontal lobe over the fore-part of the insula.

Development of the Sylvian Fissure and of the Insular District of the Cerebral Hemisphere.—It is only during the latter half of the intrauterine period of development that the opercula take shape and grow over the insula, so as to shut it out from the surface. In its early condition the insula presents the form of a depressed area on the side of the cerebral hemisphere, surrounded by a distinct boundary wall formed by the surrounding more elevated surface of the hemisphere (Fig. 447, A). After a time this depressed area, which is called the Sylvian fossa, assumes a triangular outline, and then the bounding wall is observed to be composed of three distinct parts, viz.: an upper or fronto-parietal, a lower or temporal, and an anterior or orbital part (Fig. 447, B). The rounded angle, formed by the meeting of the upper and anterior portions of the boundary, now becomes flattened, and a short oblique part of the limiting wall, termed the frontal portion, assumes shape in this position. Each of these four portions of the bounding wall of the Sylvian fossa becomes a line of growth, from which an operculum takes origin, and by the approximation of these opercula, as they grow over the surface of the Sylvian fossa, the insula becomes closed in and the limbs of the Sylvian fissure are formed (Fig. 448).

The temporal and fronto-parietal opercula make their appearance somewhere about the end of the fifth month of fœtal development, long before the other two opercula show any indication of growth. The temporal operculum grows more rapidly than the fronto-parietal; so that, when the margins of these two opercula come together to form the posterior limb of the Sylvian fissure, there is a greater extent of the Sylvian fossa covered by the temporal operculum than by the fronto-parietal operculum. This accounts for the more oblique direction of the Sylvian fissure in the fœtal brain. But at this stage a growth-antagonism between the two opercula takes place, and in this the fronto-parietal operculum proves the victor. The contiguous lips of the two opercula become, in the first instance, tightly pressed together, and then, as the upper operculum proves the stronger and the more vigorous in its growth, the posterior limb of the Sylvian fissure becomes gradually depressed until it assumes the inclination characteristic of the adult. It would appear that the opercular growth-antagonism which produces this effect in the human brain does not occur to the same extent, if indeed it occurs at all, in the ape. This is evident from the oblique direction of the posterior limb of the Sylvian fissure in the simian brain. The greater growth-energy of the fronto-parietal operculum in the human brain is not confined to the fœtal stage of development, but is carried into the earlier stages of infantile growth, and it is probable that it is due to an extension of that district of the cortex in which the centres for the skilled movements of the upper limbs reside, and also to an extension of Flechsig's parieto-occipital association area.

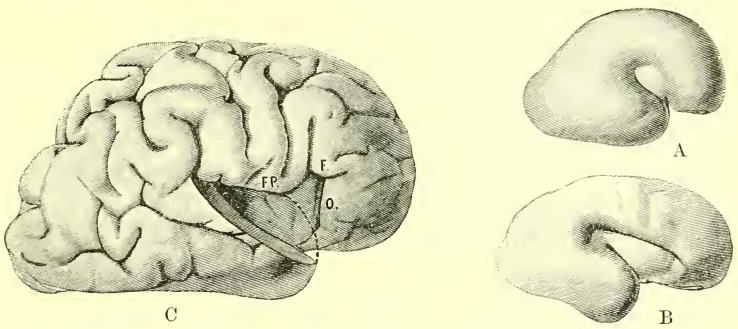


Fig. 447.—Three Stages in the Development of the Insula and the Insular Opercula.

A, Right cerebral hemisphere from a fœtus in the latter part of the fourth month of development; B, Right cerebral hemisphere from a fœtus in the fifth month of development; C, Right cerebral hemisphere from a fœtus in the latter part of the eighth month of development.

In C the temporal operculum has been removed, and thus a large part of the insula is exposed. The outline of the temporal operculum is indicated by a dotted line.

F.P. Fronto-parietal operculum. F, Frontal operculum. O, Orbital operculum.

The orbital and frontal opercula are late in appearing and very tardy in their growth. Indeed, it is only during the course of the first year of infantile life that they come into apposition

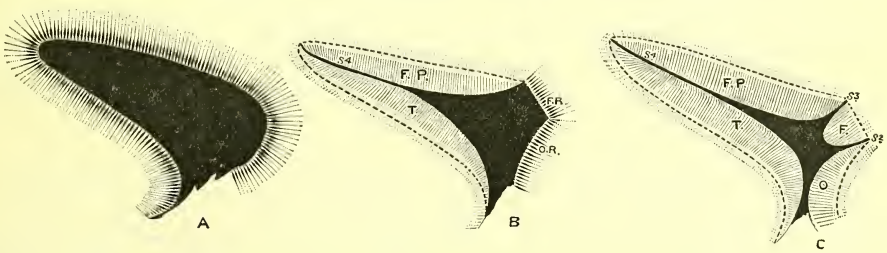


Fig. 448.—Diagram to Illustrate the Development of the Opercula which cover the Insula.

A, Sylvian fossa before opercula begin to form; B, Fronto-parietal and temporal opercula well advanced; C, All the four opercula developed but not in apposition.

F.P. Fronto-parietal operculum.
T. Temporal operculum.
F.R. Frontal wall of fossa.
O.R. Orbital wall of fossa.
F. Frontal operculum.
O. Orbital operculum.
s^2. Anterior horizontal limb of Sylvian fissure.
s^3. Ascending limb.
s^4. Posterior horizontal limb.

with each other and with the other two opercula, so as to close in the fore-part of the Sylvian fossa and form the anterior limbs of the Sylvian fissure. They do not begin to take shape until more than half of the Sylvian fossa has already been closed by the fronto-parietal and the temporal opercula. The orbital operculum appears first and is much more constant in its growth than the frontal operculum, which indeed frequently fails altogether, and, even when present, shows the greatest amount of variability in the degree to which it is developed.

Variations in the degree of development of the frontal operculum influence greatly the form presented by the two anterior limbs of the Sylvian fissure, between which it lies. When strongly developed, it separates the two Sylvian limbs from each other to such an extent that they assume the appearance of the letter U; when the frontal operculum is less strongly marked, the anterior Sylvian limbs may assume a V form or a Y form. In the latter case, the orbital and the fronto-parietal opercula meet below the frontal operculum to form the stem of the Y. In those cases

where the frontal operculum is absent altogether, a single anterior limb of the Sylvian fissure is the result.

The late appearance, the slow growth, the variability of these two opercula, and also the tendency to abortive growth or complete suppression of the frontal operculum, all bespeak the fact that, from a phylogenetic point of view, the frontal and orbital opercula are, comparatively speaking, recent productions in the evolution of the human brain. In the anthropoid ape they are absent, and, consequently, the fore-part of the island of Reil is exposed on the surface of the simian brain. The same condition is not at all an uncommon occurrence in the brain of the microcephalic idiot.

Fissure of Rolando (sulcus centralis).—The fissure of Rolando takes an oblique course across the outer convex surface of the cerebral hemisphere, and intervening between the frontal and parietal lobes it forms the immediate posterior boundary of the motor area of the cortex. Its upper end cuts the supero-mesial border of the hemisphere a short distance behind the mid-point between the frontal and occipital poles, whilst its lower end terminates above the middle of the posterior horizontal limb of the fissure of Sylvius. Its superior extremity, as a rule, turns round the supero-mesial border of the hemisphere, and is then continued backwards for a short distance on the mesial surface. Although, in its general direction, the fissure is oblique, it is very far from being straight. It takes a sinuous course across the hemisphere. This is largely due to the area of cortex which represents the motor centre for the arm, and which lies in front of the sulcus, growing backwards in the course of its development so as to produce a bay in the fissure within which this portion of the cortex is accommodated. The bends in the fissure which indicate the upper and lower limits of the arm centre (Grünbaum and Sherrington) are termed respectively the *superior* and *inferior genua*. The angle which the general direction of the fissure of Rolando makes with the mesial plane is termed the **Rolandic angle**. In the adult brain the average Rolandic angle is 71° 7′, and the limits of variation would appear to be 69° and 74°.

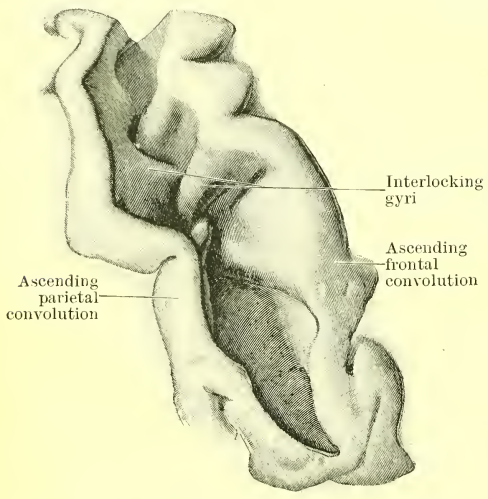


Fig. 449.—Fissure of Rolando fully opened up, so as to exhibit the interlocking gyri and deep annectant gyrus within it.

When the fissure of Rolando is widely opened up, so that its bottom and its opposed sides may be fully inspected, it will be seen that, between the two genua, the two bounding convolutions are dovetailed into each other by a number of interlocking gyri, which do not appear on the surface (Fig. 449). Further, two of these, placed on opposite sides of the fissure, are frequently joined across the bottom of the sulcus in the form of a sunken bridge of connexion, which constitutes what is termed a *deep annectant gyrus*. The continuity of the fissure is thus, to some extent, interrupted. This condition is rendered interesting when considered in connexion with the development of the sulcus. The deep interlocking gyri indicate a great exuberance of cortical growth in this situation in the early stages of the development of the fissure; and the presence of the deep annectant gyrus is explained by the fact that the fissure of Rolando generally develops in two pieces, which run into each other to form the continuous sulcus of the adult, viz. a part corresponding to the lower two-thirds, and an upper part, which represents the upper third and which appears at a slightly later date. In certain very rare cases the fissure of Rolando is found to remain double throughout life, through a failure of its two pieces to unite. In such cases the deep annectant gyrus, which is frequently seen at the bottom of the furrow, remains on the surface. Heschl, who examined 2174 cerebral hemispheres, only found this anomaly six times; Eberstaller met with it twice in 200 brains.

Parieto-occipital Fissure.—A small part of this fissure appears on the outer face of the cerebral hemisphere. For the most part it is situated on the internal surface. It is customary, therefore, to describe an external parieto-occipital and an internal parieto-occipital fissure. It must be clearly understood, however, that they are directly continuous with each other round the supero-mesial border of the

hemisphere. The parieto-occipital fissure intervenes between the parietal and occipital lobes.

The **external parieto-occipital fissure** cuts the supero-mesial border of the hemisphere in a transverse direction at a distance of from one and a half to two inches in front of the occipital pole. It is, as a rule, not more than about a half an inch long, and it is brought to an abrupt termination by an arching convolution, which winds round its extremity and receives the name of **arcus parieto-occipitalis.**

The **internal parieto-occipital fissure** is carried downwards on the inner surface of the hemisphere in a nearly vertical direction as a conspicuous and deep cleft. A short distance behind the hinder end of the corpus callosum its lower extremity runs into the calcarine fissure.

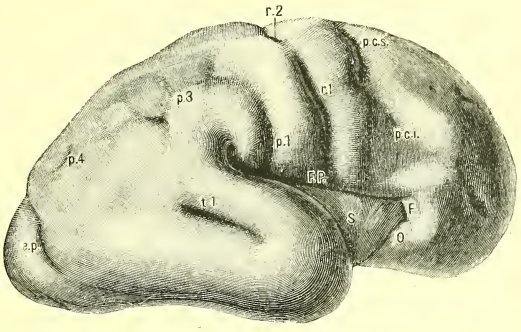


FIG. 450.—LEFT CEREBRAL HEMISPHERE, from a fœtus in the early part of the seventh month of development.

p.c.s.	Sulcus præcentralis superior.	
p.c.i.	Sulcus præcentralis inferior.	
r^1.	Lower part of Rolandic fissure.	
r^2.	Upper part of Rolandic fissure.	
p^1.	Inferior postcentral sulcus	Intraparietal fissure.
p^3.	Ramus horizontalis	
p^4.	Ramus occipitalis	
e.p.	External perpendicular fissure of Bischoff.	
t^1.	Parallel sulcus.	
S.	Sylvian fossa.	
F.P.	Fronto-parietal wall.	
F.	Frontal wall.	
O.	Orbital wall.	

The parieto-occipital fissure is developed, as a rule, after the manner of a complete fissure. In the fœtal brain it forms a very evident infolding of the cerebral wall. In the adult brain, however, it does not form any eminence on the inner wall of the ventricle, because it does not extend downwards as far as the cavity. The wall of the ventricle during the growth of the hemisphere has thickened to such an extent that the part corresponding to the fissure has become solid.

Collateral Fissure (fissura collateralis).—The collateral sulcus is a strongly-marked fissure on the tentorial face of the cerebral hemisphere. It begins near the occipital pole and extends forwards towards the temporal pole. In its posterior part it is placed below, and parallel to, the calcarine fissure, whilst in front it is

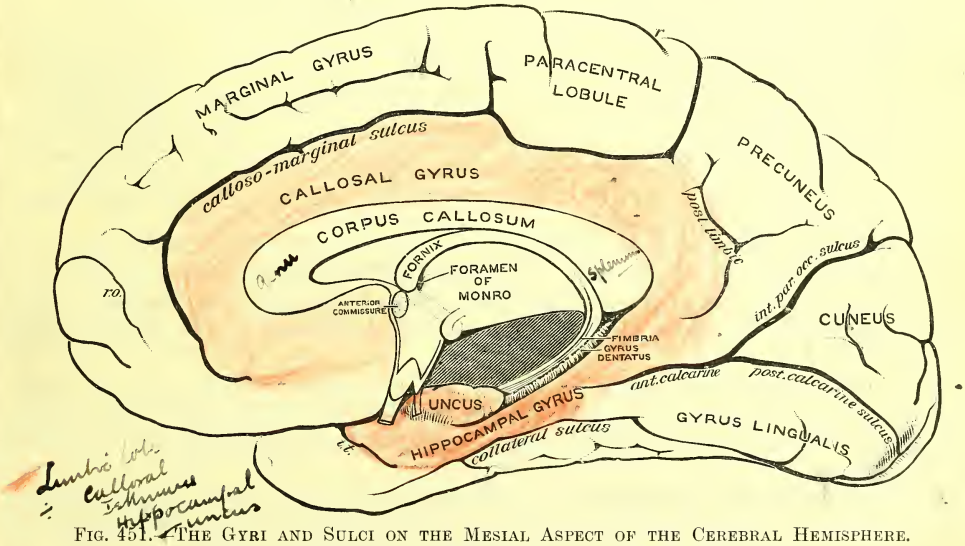


FIG. 451.—THE GYRI AND SULCI ON THE MESIAL ASPECT OF THE CEREBRAL HEMISPHERE.
r. Fissure of Rolando. *r.o.* Rostral sulcus. *i.t.* Incisura temporalis.

separated from the hippocampal or dentate fissure by the hippocampal gyrus, which is the innermost convolution on the tentorial surface of the hemisphere.

In front of the anterior extremity of the collateral fissure a shallow sulcus turns round the anterior end of the temporal lobe, so as to intervene between the temporal

pole and the uncinate or hook-like extremity of the hippocampal convolution. This is the **incisura temporalis**, or **ecto-rhinal fissure**. The collateral fissure and the incisura temporalis intervene between the limbic and temporal lobes.

The collateral fissure is developed, as a rule, in three portions—a hinder or occipital, an intermediate, and an anterior or temporal part. These ultimately run into each other and form the continuous fissure. The middle part is usually a complete fissure and responsible for the production of the *eminentia collateralis posterior* in the floor of the trigonum of the lateral ventricle; the temporal part is sometimes a complete fissure, forming when it is so the *eminentia collateralis anterior*; the occipital part is always incomplete.

Calloso-marginal Fissure.—This fissure is a strongly-marked sulcus on the fore-part of the mesial surface of the hemisphere. It divides the front portion of the mesial surface into an upper marginal and a lower callosal convolution, and intervenes between the frontal and limbic lobes. Beginning below the fore-end of the corpus callosum, close to the locus perforatus anticus, the calloso-marginal fissure curves round in front of the genu of the corpus callosum, and then extends backwards to a point a short distance behind the middle of the mesial surface. It then turns upwards and cuts the supero-mesial border of the hemisphere, immediately behind the upper end of the fissure of Rolando. The relation presented by the two extremities of these fissures is such that they can both be readily recognised either when examined on the outer or mesial aspect of the cerebrum.

The calloso-marginal sulcus is developed in two or three separate pieces, which, as growth proceeds, run into each other and form the continuous fissure. The numerous cases of irregular arrangement met with in connexion with this fissure can generally be explained by this interrupted mode of development.

Frontal Lobe.—The frontal lobe is the largest of the cerebral lobes. On the outer surface of the hemisphere, it is bounded behind by the fissure of Rolando and below by the posterior horizontal limb of the fissure of Sylvius. On the mesial face it is limited by the calloso-marginal fissure, whilst on the inferior surface of the hemisphere the stem of the Sylvian fissure forms its posterior boundary. It presents an outer surface, a mesial surface, and an inferior or orbital surface.

On the *outer surface of the frontal lobe* the following sulci and gyri may be recognised:—

- Sulci
 - Sulcus præcentralis inferior.
 - Sulcus præcentralis superior.
 - Sulcus paramedialis.
 - Sulcus frontalis superior.
 - Sulcus frontalis medius.
 - Sulcus frontalis inferior.
 - Sulcus diagonalis.
 - Sulcus fronto-marginalis.
- Gyri
 - Gyrus frontalis ascendens or gyrus centralis anterior.
 - Gyrus frontalis superior
 - pars superior.
 - pars inferior.
 - Gyrus frontalis medius
 - pars superior.
 - pars inferior.
 - Gyrus frontalis inferior
 - pars basilaris.
 - pars triangularis.
 - pars orbitalis.

The **inferior præcentral sulcus** consists of a vertical and a horizontal part, and when developed in a typical manner, it presents a figure like the letter T or F. The *vertical portion* lies in front of the lower part of the fissure of Rolando, whilst the *horizontal part* extends obliquely forwards and upwards into the middle frontal convolution.

The **superior præcentral sulcus** is a short vertical sulcus which lies at a higher level than the inferior præcentral furrow, in front of the upper part of the fissure of Rolando. It is almost invariably connected with the hinder end of the superior frontal sulcus.

The **anterior central convolution** (ascending frontal gyrus) is a long continuous gyrus, which is limited in front by the two præcentral furrows and behind by the fissure of Rolando. It extends obliquely across the hemisphere from the supero-mesial margin above to the posterior horizontal limb of the Sylvian fissure below.

The **superior frontal sulcus** extends forwards in a more or less horizontal direction from the sulcus præcentralis superior.

The **gyrus frontalis superior** is the narrow convolution between the supero-mesial

border of the hemisphere and the superior frontal sulcus. It takes a horizontal course to the frontal pole.

The **inferior frontal sulcus** occupies a lower level than the superior frontal furrow. Its hinder end is placed in the angle between the vertical and horizontal parts of the inferior præcentral sulcus, and is not infrequently confluent with one or other of these. It proceeds forwards towards the superciliary margin of the hemisphere and ends a short distance from this in a terminal bifurcation.

The **gyrus frontalis medius** is the name given to the broad convolution which lies between the superior and inferior frontal sulci.

The **gyrus frontalis inferior** is that portion of the outer surface of the frontal lobe which is placed in front of the inferior præcentral sulcus and below the inferior frontal sulcus. The inferior frontal convolution is cut into three pieces by two anterior limbs of the Sylvian fissure. These are termed the pars basilaris, the pars triangularis, and the pars orbitalis.

The **pars basilaris** is that part which lies between the vertical limb of the inferior præcentral sulcus and the ascending limb of the Sylvian fissure. It forms the anterior part of the fronto-parietal operculum, and it is traversed in an oblique direction by a shallow but constant furrow, termed the **sulcus diagonalis**. The **pars triangularis** is simply another name for the frontal operculum. It is triangular in form, and lies between the anterior ascending and the anterior horizontal limbs of the Sylvian fissure. The **pars orbitalis** is placed below the anterior horizontal limb of the Sylvian fissure.

The inferior frontal convolution possesses a special interest on account of the localisation within it, on the left side, of the speech centre. From it, also, the front part of the fronto-parietal and the whole of the frontal operculum are developed. This opercular development in connexion with the inferior frontal gyrus constitutes a leading point of difference between the brain of man and that of the ape. Even in the highest ape the inferior frontal convolution is not opercular. The frontal operculum is not present and the anterior part of the insula is exposed on the surface. Probably the excess of growth which determines the formation of the frontal operculum in man has some connexion with the development of the speech centre.

The **sulcus paramedialis** is the term applied to a series of short irregular depressions or furrows, arranged longitudinally, close to the supero-mesial border of the hemisphere. These rudimentary sulci partially subdivide the superior frontal convolution into an upper and a lower part, and they are of interest in so far that they are not as a rule developed in the higher apes, and are deeper and better marked in the higher than the lower types of human brain.

The **sulcus frontalis medius** (Eberstaller) proceeds horizontally forwards in the forepart of the middle frontal convolution, so as to subdivide it into an upper and a lower part. When the furrow reaches the superciliary margin of the hemisphere it bifurcates, and its terminal branches spread out widely and constitute a transverse furrow, called the *fronto-marginal sulcus*. The sulcus frontalis medius is only found in man and the anthropoid apes. It is not present in any of the lower apes.

Owing to the subdivision of the superior and middle frontal convolutions in the manner indicated, the typical arrangement of the convolutions in the anterior part of the outer surface of the frontal lobe is in five horizontal tiers, and not in three tiers, as formerly described.

As a rule, the sulci on the outer surface of the frontal lobe during the process of development appear in the following order: (1) sulcus præcentralis inferior; (2) sulcus frontalis inferior; (3) sulcus præcentralis superior and sulcus frontalis superior; (4) sulcus frontalis medius; (5) sulcus paramedialis. This gives some indication of the relative morphological importance of these sulci, although it should be borne in mind that the period at which sulci appear on the fœtal brain cannot in every case be taken as affording an infallible guide in our attempts to assign to them their relative morphological value.

On the *mesial aspect of the frontal lobe* there is an elongated more or less continuous convolution, called the **gyrus marginalis**. It lies between the supero-mesial margin of the hemisphere and the calloso-marginal fissure. In the fore-part of this gyrus one or two curved sulci are usually present. They are termed the **sulci rostrales**. The posterior part of the marginal convolution is more or less completely cut off from the portion which lies in front. This part is called the

paracentral lobule, and into it the upper end of the fissure of Rolando is prolonged as it turns over the supero-mesial border of the hemisphere.

On the *orbital aspect of the frontal lobe* there are two sulci, viz. the olfactory and the orbital.

The **olfactory sulcus** is a straight furrow which runs parallel to the mesial border of the hemisphere. It is occupied by the olfactory tract and bulb, and it cuts off a narrow strip of the orbital surface close to the mesial border, which receives the name of **gyrus rectus.**

The **orbital sulcus** is a composite furrow which assumes many different forms. As a general rule it presents a shape similar to that of the letter H, and is then composed of three parts, viz. an external limb, an internal limb, and a transverse limb. The **external limb** (sulcus orbitalis externus) curves round the orbital part of the inferior frontal convolution, so as to limit it on this aspect of the brain. The **internal limb** (sulcus orbitalis internus) is frequently broken up into two pieces. It marks off a convolution between itself and the olfactory sulcus, called the **gyrus orbitalis internus.** The **transverse limb** (sulcus orbitalis transversus) takes a curved course between the internal and external limbs. The district in front is termed the **gyrus orbitalis anterior**, and that behind the **gyrus orbitalis posterior.** The latter, in its outer part, corresponds with the orbital operculum.

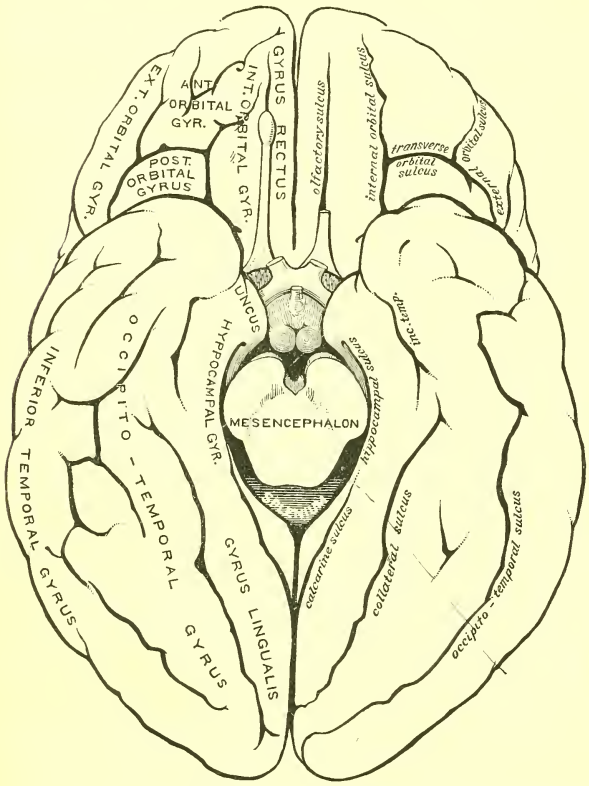


FIG. 452.—GYRI AND SULCI on the tentorial and orbital aspects of the cerebral hemispheres.

PARIETAL LOBE. — The parietal lobe forms a considerable part of the external surface of the cerebral hemisphere, and it also appears on the inner surface in the form of the præcuneus or the quadrate lobule. *In front*, it is bounded by the fissure of Rolando, which separates it from the frontal lobe. *Below*, it is limited in its fore-part by the posterior horizontal limb of the fissure of Sylvius. Behind the upturned end of this fissure the surface of the parietal lobe is continuous inferiorly with that of the temporal lobe, and an arbitrary line drawn backwards on the surface of the brain, in continuation of the horizontal part of the posterior limb of the Sylvian fissure, is taken as its inferior limit. *Posteriorly*, it is separated from the occipital lobe at the supero-mesial border of the hemisphere by the external parieto-occipital fissure. Below this fissure the surface of the parietal lobe is continuous with that of the occipital lobe; and an arbitrary line drawn across the outer surface of the hemisphere, from the extremity of the external parieto-occipital fissure to an indentation on the infero-lateral border of the hemisphere, termed the **præoccipital notch**, may be regarded as furnishing a posterior limitation.

The præoccipital notch is, as a rule, only visible in brains that have been hardened *in situ*. It is placed on the infero-lateral border of the hemisphere, about an inch and a half in front of the occipital pole, and is produced by a vertical fold or wrinkle of the dura mater on the deep aspect of the parieto-mastoid suture, and immediately above the highest part of the lateral blood-sinus.

There is great variability in the degree to which this fold of dura mater projects in different

individuals. In the child it is always very salient, and often produces a deep cleft in the brain, but as the full size of the cranium is gradually attained it becomes much less projecting. In the young skull two or three such folds in this locality are frequently apparent. Related to the præoccipital notch there are likewise some cerebral veins which turn round the infero-lateral margin of the hemisphere to join the lateral blood-sinus.

On the *mesial surface of the hemisphere* the parietal lobe is represented by the **præcuneus** or **quadrate lobule.** This district, which is somewhat quadrilateral in form, lies between the upturned end of the calloso-marginal sulcus and the internal parieto-occipital fissure. It is imperfectly separated below from the limbic lobe by a somewhat variable furrow called the **post-limbic sulcus.**

The gyri and sulci, on the *outer surface of the parietal lobe,* are the following :—

- Sulci
 - Sulcus intraparietalis (of Turner).
 - Sulcus postcentralis inferior.
 - Sulcus postcentralis superior.
 - Ramus horizontalis.
 - Ramus occipitalis.
 - Upturned ends of—
 - (*a*) Sylvian fissure.
 - (*b*) Parallel fissure.
 - (*c*) Second temporal fissure.
- Gyri
 - Gyrus ascendens parietalis or gyrus postcentralis.
 - Gyrus parietalis superior.
 - Gyrus parietalis inferior
 - Gyrus supramarginalis.
 - Gyrus angularis.
 - Gyrus postparietalis.

The **intraparietal sulcus** (of Turner) is a composite furrow, and is built up of four originally distinct factors. Two of these, termed the sulcus postcentralis inferior and the sulcus postcentralis superior, take a more or less oblique course across the hemisphere, and are most frequently united into one continuous fissure. The other two factors are placed horizontally, one behind the other, and are termed the ramus horizontalis and the ramus occipitalis.

The **sulcus postcentralis inferior** lies behind the lower part of the fissure of Rolando, whilst the **sulcus postcentralis superior** occupies a similar position in relation to the upper part of that fissure. When confluent they form a long, continuous fissure, which stretches across the hemisphere behind the fissure of Rolando and parallel to it.

The **ramus horizontalis** is continuous, as a rule, with the upper end of the sulcus postcentralis inferior, and extends backwards, with a slight inclination upwards between the superior parietal gyrus, which lies above it, and the inferior parietal gyrus, which is placed below it. With the two confluent postcentral sulci it presents a figure like the letter ⊣ placed on its side.

The **ramus occipitalis** is a curved sulcus which bounds externally the arcus parieto-occipitalis, or, in other words, the arching convolution which surrounds the external parieto-occipital fissure. The ramus occipitalis lies behind the ramus horizontalis, and is generally linked on to it; less frequently it is separate. The posterior end of the ramus occipitalis enters the occipital lobe, and, behind the arcus parieto-occipitalis, bifurcates into two widely spread-out branches. These form a short transverse fissure in the occipital lobe, termed the **sulcus occipitalis transversus.**

In the human brain the intraparietal sulcus is usually developed in four separate pieces, corresponding to the four portions of the fissure which have been described as being present in the adult brain. The sulcus postcentralis inferior appears first (somewhere about the end of the sixth month), then the ramus occipitalis and the ramus horizontalis; last of all the sulcus postcentralis superior comes into view. The further development of the sulcus consists in the running together of these early pieces. This takes place in different ways, and not infrequently union fails at one or more points, and thus a great variety of combinations may be noted in different individuals; indeed, it may be said that every possible kind of combination may be met with. The most common form which the fissure assumes, however, is that in which all its factors have become confluent and one continuous furrow results. When such an intraparietal furrow is widely opened up, certain deep annectant gyri, which cross the bottom of the sulcus, come into view. These interrupt the sulcus at the points of union between its several pieces and indicate its original multiple formation.

There is reason to believe that three of the elements of the human intraparietal sulcus, viz. the sulcus postcentralis inferior, the ramus horizontalis, and the ramus occipitalis, are disrupted portions of the primitive single continuous fissure which is seen in certain of the lower apes (Cebus), whilst one, the sulcus postcentralis superior, is a superadded element.

There is a strong analogy between the postcentral sulcus, the fissure of Rolando, and the

præcentral sulcus. They form a group of radial sulci on the outer surface of the fœtal cerebrum above the Sylvian region. The fissure of Rolando makes its appearance first, then the præcentral sulcus, and, lastly, the postcentral sulcus. Each assumes shape in the first instance in two pieces, viz. an upper and lower. The two pieces of the fissure of Rolando join early, and only in very rare instances remain separate; the two pieces of the postcentral furrow usually join, but in 19 per cent of cerebral hemispheres they remain separate; the two pieces of the præcentral furrow, as a rule, remain separate and distinct.

The **sulcus transversus occipitalis**, or bifurcated extremity of the ramus occipitalis, has been

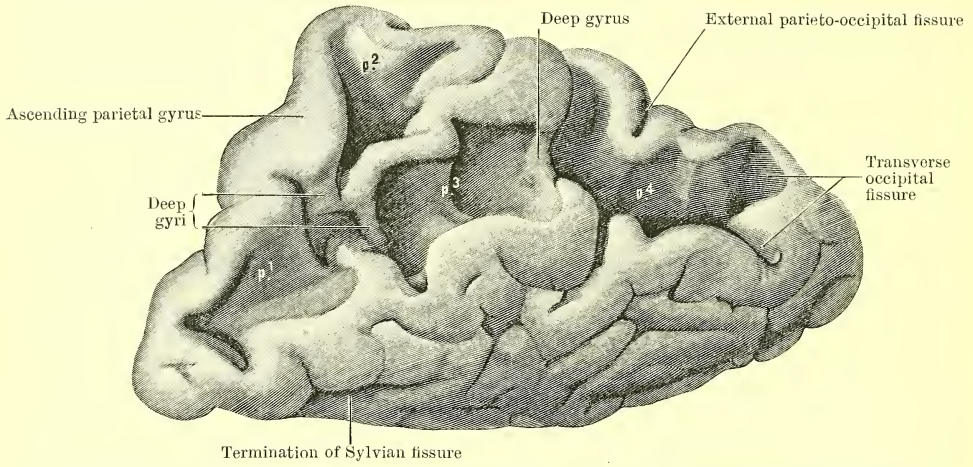


FIG. 453.—THE INTRAPARIETAL SULCUS FULLY OPENED UP, so as to show its several parts and the deep annectant gyri intervening between them.

p^1. Sulcus postcentralis inferior.
p^2. Sulcus postcentralis superior.
p^3. Ramus horizontalis.
p^4. Ramus occipitalis.

until lately generally believed to be the representative in the human brain of the conspicuous "Affenspalte," in the cerebrum of the ape. The accuracy of this view was challenged in 1892 (*Cunningham Memoir*, No. vii. Roy. Irish Acad.), and recently Elliot Smith has brought forward evidence of a very convincing kind which seems to show that in the human brain the "Affenspalte" is represented by the sulcus occipitalis lateralis of Eberstaller.

The intraparietal sulcus maps out three districts or gyri on the external surface of the parietal lobe, viz. the posterior central convolution, the superior parietal gyrus, and the inferior parietal gyrus.

The upturned ends of the fissure of Sylvius, of the first temporal or parallel sulcus, and of the second temporal sulcus ascend for a short distance, one behind the other, into the inferior parietal gyrus.

The **posterior central convolution** (ascending parietal convolution) is a long gyrus which extends obliquely across the hemisphere from the supero-mesial border above to the Sylvian fissure below. It is bounded in front by the fissure of Rolando and behind by the superior and inferior postcentral sulci.

The **superior parietal gyrus** is the area of cerebral cortex which lies between the supero-mesial border of the hemisphere above and the ramus horizontalis below. In front it is bounded by the superior postcentral sulcus, whilst behind it is connected with the occipital lobe by the arcus parieto-occipitalis. It is continuous round the supero-mesial border with the præcuneus.

The **inferior parietal gyrus** lies below the ramus horizontalis and the ramus occipitalis and behind the inferior præcentral sulcus. It is more or less directly continuous with the occipital lobe behind and the temporal lobe below. From before backwards it presents three arching convolutions, viz. the supra-marginal, the angular, and the postparietal. The **supramarginal convolution** is bent round the upturned end of the posterior limb of the Sylvian fissure, and stands in continuity behind and below this, with the first temporal gyrus. The **angular convolution** arches over the upturned end of the parallel sulcus and becomes continuous with the second temporal convolution. The **postparietal convolution** winds round the upturned end of the second temporal sulcus and runs into the third temporal gyrus.

OCCIPITAL LOBE.—The occipital lobe forms the hinder pyramidal part of the

cerebral hemisphere; and although very imperfectly mapped off from the temporal and parietal lobes, which lie in front of it, it is nevertheless one of the most natural subdivisions of the cerebral hemisphere. It is not developed in the brain of the quadruped. Man and the ape alone possess a well-marked occipital lobe, and it may be defined as being that part of the hemisphere which encloses the posterior horn of the lateral ventricle. Being pyramidal in form, it presents three surfaces and an apex or occipital pole. On the mesial aspect of the hemisphere it is separated from the parietal lobe (*i.e.* the præcuneus) by the internal parieto-occipital fissure. On the tentorial or inferior surface it is not marked off in any way from the temporal lobe and the limbic lobe, which lie in front of it. It is necessary, therefore, on this aspect to employ an arbitrary line of demarcation; one which extends from the præoccipital notch on the infero-lateral border of the hemisphere to the isthmus of the limbic lobe (*i.e.* the narrow part of the limbic lobe immediately below the hinder end of the corpus callosum) will serve the purpose. On the external surface the external parieto-occipital fissure, and an arbitrary line from this to the præoccipital notch, may be regarded as separating the occipital from the parietal and temporal lobes. The upturned end of the second temporal sulcus may lie in the course of this line.

On the *mesial aspect of the occipital lobe* we find: (1) the calcarine fissure, (2) the cuneus, and (3) the gyrus lingualis.

The **calcarine fissure** begins on the occipital pole by a bifurcated extremity, which lies in the groove which is formed on this part of the brain by the lateral sinus. From this it pursues a slightly arched course forwards, and ends by cutting into the limbic lobe immediately below the splenium or thickened hinder margin of the corpus callosum. The calcarine fissure is joined by the internal parieto-occipital fissure at a point somewhat nearer its anterior than its posterior extremity. Together, the two fissures present a ≺-shaped figure. Between the two limbs of the Y is placed the cuneus.

If the calcarine and internal parieto-occipital fissures are opened up so as to expose the bottom in each case, three well-marked deep or submerged annectant gyri will usually be displayed. One of these, the best marked, called the **gyrus cunei**, marks off the parieto-occipital from

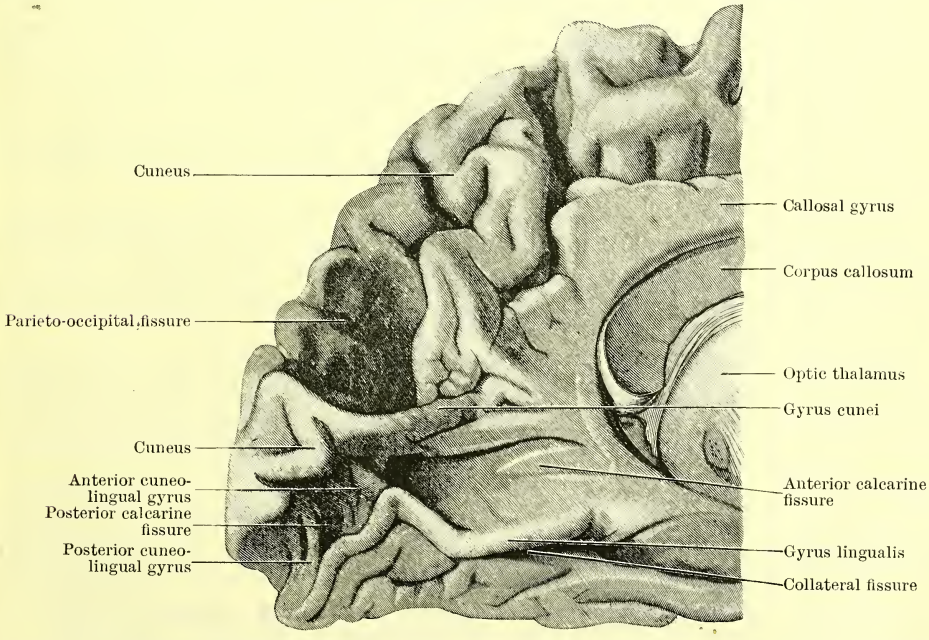


FIG. 454.—INTERNAL PARIETO-OCCIPITAL AND THE CALCARINE FISSURES FULLY OPENED UP, so as to show the deep annectant gyri marking off the several elements of the ≺-shaped system.

the calcarine fissure and joins the cuneus with the limbic lobe. In the chimpanzee and in the lower apes the gyrus cunei is on the surface, and there is no communication between the two fissures; in the orang, gibbon, and microcephalic idiot, it may either be submerged or on the

surface. The second deep annectant gyrus, termed the **anterior cuneo-lingual,** crosses the bottom of the calcarine fissure a short distance behind the point where it is joined by the parieto-occipital fissure, and divides it into an anterior and a posterior part. The **anterior calcarine fissure** is slightly longer and much deeper than the posterior part. It includes the whole of the stem of the Y-shaped fissural arrangement and extends backwards for a short distance into the cuneus. It is the complete part of the fissure and gives rise to an elevation on the inner wall of the posterior horn of the lateral ventricle, to which the name of calcar avis or hippocampus minor is given. The **posterior calcarine fissure** is shallower and is usually interrupted by the third deep annectant gyrus, viz. the **posterior cuneo-lingual**; this divides it into two parts, of which the

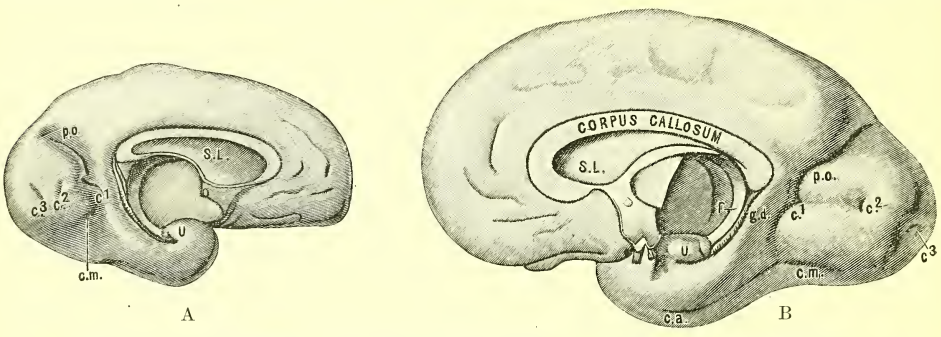


Fig. 455.—Development of the Parieto-occipital and the Calcarine Fissures.

A, Mesial aspect of a left cerebral hemisphere of a fœtus approaching the end of the fifth month of development; B, Mesial aspect of a right cerebral hemisphere of a fœtus in the beginning of the seventh month of development.

S.L. Septum lucidum.
f. Fornix.
U. Uncus.
g.d. Gyrus dentatus.
p.o. Parieto-occipital fissure.
c^1. Anterior calcarine fissure.
c^2. c^3. Two parts of posterior calcarine fissure.
c.a. Anterior collateral fissure.
c.m. Mid-collateral fissure.

hinder is little more than the bifurcated extremity of the fissure. Very frequently this deep gyrus reaches the surface, and then the hinder end of the sulcus is completely cut off. The posterior calcarine fissure is not a complete fissure.

When the manner in which the calcarine fissure is developed is studied, the various appearances which come into view when the bottom of the adult fissure is inspected receive the fullest explanation. The anterior calcarine fissure is formed very early as an infolding of the wall of the cerebral hemisphere. The posterior calcarine fissure is a secondary formation. It appears much later, and usually in two pieces, which run together and then join the anterior calcarine fissure. The points of union are indicated in the adult by the two cuneo-lingual deep gyri.

The **cuneus** is the wedge-shaped or triangular district, on the mesial aspect of the occipital lobe, which lies between the internal parieto-occipital and calcarine fissures.

The **gyrus lingualis** is a well-marked convolution between the calcarine fissure above and the posterior part of the collateral fissure below, which stretches forwards from the occipital pole. Anteriorly, it becomes very narrow and joins the hippocampal part of the limbic lobe. It lies partly on the mesial surface and partly on the tentorial surface of the occipital lobe.

On the *tentorial surface of the occipital lobe* there is only one convolution, viz. the posterior part of the **occipito-temporal gyrus.** It proceeds continuously forwards into the temporal lobe on the outer side of the collateral fissure, and is bounded externally by the **occipito-temporal sulcus,** a furrow which is rarely continuous, but is usually represented by a series of detached pieces.

There are two well-marked sulci on the *external surface of the occipital lobe,* viz. the sulcus occipitalis transversus and the sulcus occipitalis lateralis. The **sulcus occipitalis transversus** extends transversely across the upper part of the lobe, behind the arcus parieto-occipitalis. As already explained, it is the terminal bifurcation of the ramus occipitalis of the intraparietal sulcus. The **sulcus occipitalis lateralis** is a short horizontal, often sharply-curved, furrow, which divides the outer surface of the lobe into an upper and a lower area of very nearly equal extent. These areas are connected by superficial annectant gyri with the parietal and temporal lobes.

Elliot Smith has brought forward very convincing proof in favour of regarding the sulcus occipitalis lateralis as the representative of the "Affenspalte" in the brain of the

ape. He calls it the **sulcus lunatus occipitalis**, and shows that in the brains of Egyptian Fellaheen it not infrequently possesses an operculum, and presents an appearance which closely corresponds with the condition distinctive of the gorilla. The same may occasionally be seen in the brain of the aboriginal Australian.

Temporal Lobe.—The temporal lobe lies behind the stem and below the posterior horizontal limb of the Sylvian fissure. It is somewhat pyramidal in form, and presents an upper, an outer, and a tentorial surface, with a free projecting apex or pole. Above, it is bounded by the posterior horizontal limb of the fissure of Sylvius, together with the artificial line which is drawn backwards from this. On the tentorial face it is separated from the hippocampal part of the limbic lobe by the collateral fissure, whilst behind it is marked off from the occipital lobe by the artificial lines already described. The temporal pole projects forwards on the under surface of the brain beyond the stem of the Sylvian fissure. It should be noticed that the recurved end of the hippocampal part of the limbic lobe (uncus), which lies to the inner side of the temporal pole, does not extend so far forwards as the latter, and is separated from the pole by the incisura temporalis or ecto-rhinal fissure.

The *upper or opercular surface of the temporal lobe* is turned towards the island of Reil and the fronto-parietal operculum. The fissure of Sylvius must, therefore, be widely opened up to expose it. For the most part the surface is smooth, but towards the back part there are a few transverse furrows, which separate two or three weakly-expressed gyri.

The anterior transverse gyrus is much more strongly expressed in the fœtal than in the adult brain. It appears in the early part of the seventh month, and is only subsequently completely hidden within the Sylvian fissure. The fact of the auditory centre being localised in this region of the temporal lobe makes this fact of interest.

On the deep surface of the temporal pole there are also a few feeble furrows.

On the *outer surface of the temporal lobe* there are two horizontal sulci, called respectively the first temporal or parallel and the second temporal sulcus.

The **parallel sulcus** is a long, continuous, and deep fissure, which begins near the temporal pole and proceeds backwards below the posterior limb of the Sylvian fissure. Its hinder end turns upwards into the parietal lobe and is surrounded by the angular gyrus. The **second temporal sulcus** is placed midway between the parallel sulcus and the infero-lateral border of the hemisphere. It is very rare to find it in the form of a continuous cleft; usually it is broken up into several isolated pieces, one behind the other. Its hinder part, which turns upwards into the parietal lobe, lies close to the artificial line of demarcation between the occipital and parietal lobes, and is surrounded by the postparietal gyrus.

By the two temporal sulci the outer surface of the temporal lobe is mapped out into three tiers of horizontal convolutions, which are termed the **first, second**, and **third temporal gyri**.

On the *tentorial surface of the temporal lobe* there is one fissure, termed the occipito-temporal sulcus. The **occipito-temporal sulcus** lies to the outer side of the collateral fissure and close to the infero-lateral margin of the hemisphere. It runs in an antero-posterior direction, and is not confined to the temporal lobe, but extends backwards towards the occipital pole. It is usually broken up into two or more separate pieces.

The **occipito-temporal convolution** is situated between the collateral fissure and the occipito-temporal sulcus. It extends from the occipital pole behind to the temporal pole in front.

The narrow strip of surface on the outer side of the occipito-temporal sulcus is continuous, round the infero-lateral margin of the hemisphere, with the third temporal convolution on the outer surface of the cerebrum, and may be reckoned as a part of it.

The three temporal convolutions and the occipito-temporal convolutions run into each other at the temporal pole.

Island of Reil or Insula.—The insula is a triangular and somewhat bulging field of cerebral cortex, which lies on a deeper plane than the general surface of the hemisphere and is hidden from view by the four opercula which overlap it. It is circumscribed by a limiting sulcus (sulcus circularis), already described, and its

dependent apical part, which is directed downwards, is in close relation to the anterior perforated spot and the Sylvian vallecula. Here the limiting sulcus is absent and the gray matter on the surface of the insula passes continuously into the anterior perforated spot. The place of transition is called the **limen insulæ**.

The insula is divided into several diverging convolutions by a series of radiating sulci. Of the latter, one, which presents the same direction and lies in the same plane as the fissure of Rolando, receives the name of the **sulcus centralis insulæ** (Fig. 447, C, p. 557). It divides the insula into an anterior *frontal part* and a posterior *parieto-limbic part.*

Limbic Lobe.—This lobe is seen on the mesial surface of the hemisphere in the form of an elongated ring-like convolution, the extremities of which approach closely to each other at the locus perforatus anticus. These extremities are connected by the roots of the olfactory tract, and in this manner the limbic ring may be considered to be closed. The upper part of the limbic lobe is placed in intimate relation to the extremities and upper surface of the corpus callosum, and receives the name of callosal convolution or gyrus fornicatus. The lower portion of the lobe is termed the hippocampal convolution and forms the inner part of the tentorial surface of the hemisphere. The continuity between the hippocampal gyrus and the callosal convolution is established below the hinder end of the corpus callosum by a narrow portion of the limbic lobe, called the isthmus. From this point the hippocampal convolution extends forwards towards the temporal pole. Finally, on the side of the crus cerebri, the hippocampal gyrus is folded back on itself and ends in a recurved hook-like extremity called the uncus. The uncus does not reach so far forwards as the temporal pole.

The **callosal convolution** begins below the anterior end of the corpus callosum at the locus perforatus anticus, and, winding round the genu of the corpus callosum, it is continued backwards on its upper surface to its hinder thickened extremity or splenium. Curving round this, it becomes greatly narrowed through the calcarine fissure cutting into it. This narrow part is termed the **isthmus**, and constitutes the link of connexion between the callosal gyrus and the hippocampal gyrus. The callosal gyrus is separated from the marginal convolution by the calloso-marginal fissure, and behind this it is imperfectly marked off from the præcuneus by the post-limbic sulcus. The furrow which separates it from the corpus callosum is termed the **callosal sulcus.**

The **hippocampal convolution** is bounded on the outer side by the anterior part of the collateral fissure, and in front of this by the incisura temporalis, which separates its hooked extremity, or **uncus**, from the temporal pole. On the inner side it is limited by the hippocampal or dentate fissure, whilst posteriorly it is divided into two parts by the anterior extremity of the calcarine fissure. Of these, the upper is the isthmus, which connects it with the callosal gyrus, whilst the lower portion brings it into continuity with the gyrus lingualis. The surface of the hippocampal convolution is covered by a white reticular stratum of fibres, termed the *substantia reticularis alba.*

Although the hippocampal convolution and uncus in descriptive anatomy are classed together there is a marked morphological distinction between them. The uncus is the feeble representative in man of the important pyriform lobe in certain of the lower mammals, and consequently it belongs to the *rhinencephalon*; the hippocampal convolution, on the other hand, is to be regarded as forming a part of the *neo-pallium* of Elliot Smith. The unimportant incisura temporalis of the human brain in lower types of brain in which the rhinencephalon bulks largely is represented by the conspicuous *ecto-rhinal fissure.*

Gyrus Dentatus and the Fimbria.—If the dentate fissure, which lies along the inner side of the hippocampal convolution, be opened up, the gyrus dentatus and the fimbria, lying side by side, will be brought into view (Fig. 451, p. 559).

The **fimbria** is simply a portion of the posterior pillar of the fornix prolonged into this region. It is a conspicuous band of white matter, which presents a prominent free border. In front it runs into the recurved extremity of the uncus, whilst, if traced backwards, it will be seen to curve upwards behind the posterior end of the optic thalamus and become continuous with the posterior pillar of the fornix below the hinder part of the corpus callosum.

The **gyrus dentatus** is the free edge of gray matter which is placed between the fimbria and the deep part of the upper surface of the hippocampal convolution. The groove between it and the fimbria is termed the **fimbrio-dentate sulcus**, whilst the furrow between it and the hippocampal convolution forms the bottom of the **dentate fissure**. The dentate gyrus is notched along the margin, whilst its surface is scored by numerous parallel and closely-placed transverse grooves. It begins behind in the region of the splenium or thickened posterior margin of the corpus

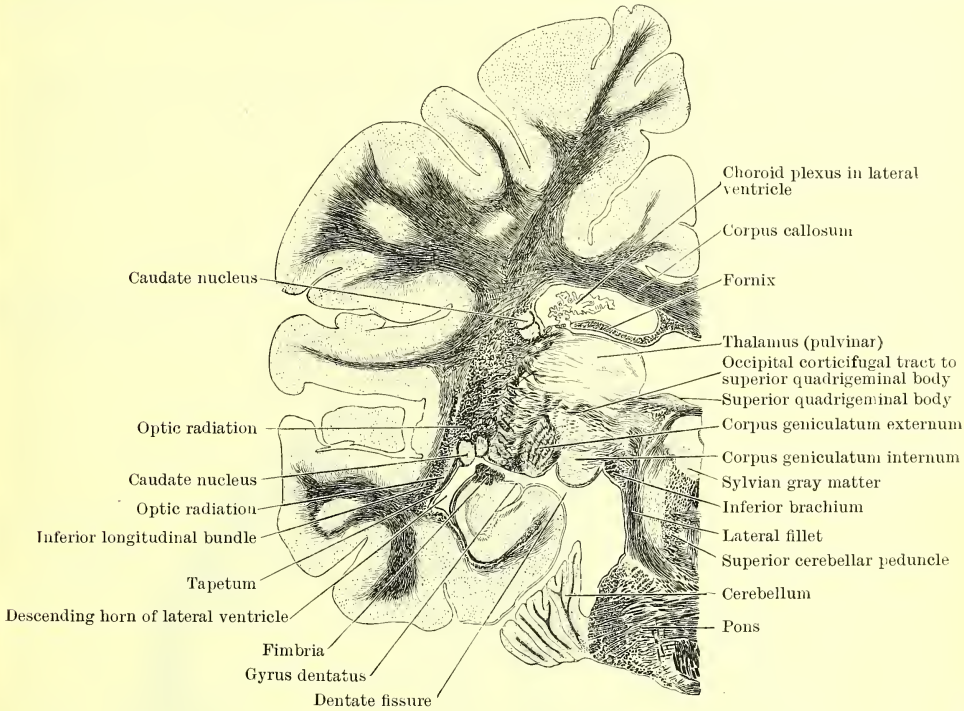


FIG. 456.—CORONAL SECTION THROUGH THE LEFT SIDE OF THE CEREBRUM, MESENCEPHALON, AND PONS, IN THE REGION OF THE PULVINAR OF THE THALAMUS AND THE CORPORA GENICULATA (Chimpanzee ; Weigert-Pal specimen).

callosum, and is carried forwards into the cleft of the uncus. From this it emerges in the form of a delicate band, which crosses the surface of the recurved part of the uncus in a transverse direction, thereby constituting the *frenulum Giacomini*.

The **dentate fissure** is a complete fissure, and the elevation on the ventricular wall which corresponds to it is called the hippocampus major. It begins behind the splenium of the corpus callosum, where it is continuous with a shallow part of the callosal fissure, and it proceeds forwards between the gyrus dentatus and the hippocampal convolution. Its anterior end is enclosed within the uncus.

When coronal sections are made through the callosal part of the limbic lobe and the subjacent corpus callosum, the cortical gray matter is seen to be reflected from the bottom of the callosal fissure in the form of an exceedingly fine layer, which forms a thin coating for the upper surface of the corpus callosum. In the midst of this certain delicate strands of longitudinal fibres, the **striæ longitudinales**, are embedded, and, with the gray matter associated with them, they represent an aborted or vestigial convolution, termed the **gyrus supracallosus**. This gyrus is continuous with the gyrus dentatus round the hinder margin of the corpus callosum.

OLFACTORY LOBE.—The olfactory lobe is small and rudimentary in the human brain, and the description which is given here does not include all the parts which, from the morphological point of view, belong to this portion of the cerebral hemisphere (see p. 584). Under this heading we shall study merely: (1) the olfactory bulb and tract, with the two roots of the latter; (2) the trigonum olfactorium.

The **olfactory tract** is a narrow, white, prismatic band, which expands anteriorly into a swollen bulbous extremity, termed the **olfactory bulb**. Both the tract and the bulb lie upon the olfactory sulcus on the orbital surface of the frontal lobe,

whilst the inferior surface of the bulb rests on the cribriform plate of the ethmoid bone, and receives the numerous olfactory nerves which reach it through the foramina in that part of the cranial floor.

Posteriorly, the olfactory tract divides into two diverging roots. The **mesial root** curves abruptly inwards and is continued into the callosal and sub-callosal gyri. The **lateral root** runs outwards and backwards over the outer part of the locus perforatus anticus, and gradually disappears from view. In animals, in which the olfactory apparatus is better developed than in man, it may be traced into what corresponds to the uncinate extremity of the hippocampal convolution in man (Fig. 380, p. 474).

The **trigonum olfactorium** or olfactory tubercle is the small triangular field of gray matter which occupies the interval between the roots of the olfactory tract at the point where they begin to diverge. Some fibres from the posterior end of the olfactory tract enter the trigonum, and, in certain cases, these constitute a more or less distinct **middle root.**

Corpus Callosum, Septum Lucidum, and Fornix.

Corpus Callosum.—The corpus callosum is the great transverse commissure which passes between the two cerebral hemispheres. It is placed nearer the anterior

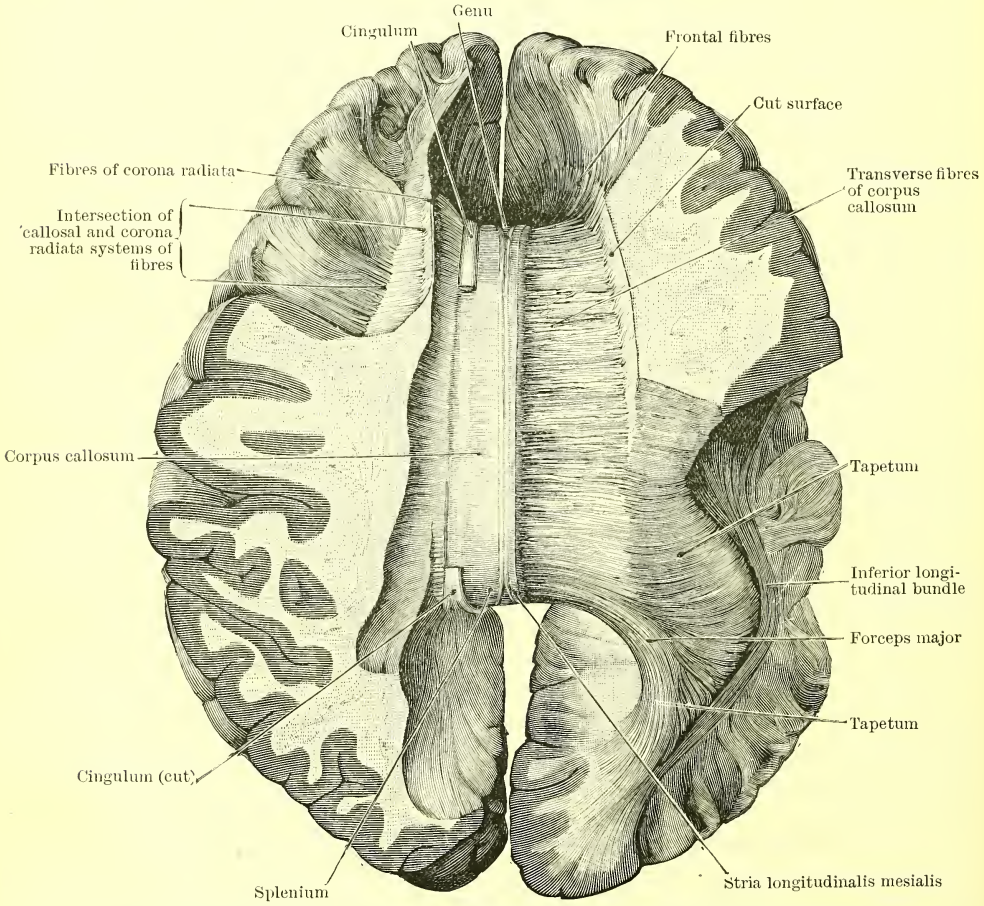


Fig. 457.—The Corpus Callosum, exposed from above and the right half dissected, to show the course taken by its fibres.

than the posterior aspect of the brain, and it unites the inner surfaces of the hemispheres throughout very nearly a half of their antero-posterior length. The corpus callosum is highly arched from before backwards, and presents a convex upper surface and a concave lower surface.

The *upper surface* of the corpus callosum forms the bottom of the great longitudinal fissure, and on each side of this it is covered by the callosal gyrus. Only in its posterior part is it touched by the falx cerebri; in front, this process of dura mater falls considerably short of it. The upper surface of the callosum is covered by a thin layer of gray matter continuous at the bottom of the callosal sulcus with the gray cortex on the surface of the hemisphere. In this there are embedded on either side of the mesial plane two delicate longitudinal bands of fibres, called respectively the stria longitudinalis medialis and lateralis. The **stria longitudinalis medialis** is the more strongly marked of the two, and it is separated from its neighbour of the opposite side by a faint mesial furrow. The **stria longitudinalis lateralis** is placed farther out, under cover of the callosal gyrus. The thin coating of gray matter, with the two striæ, represents an aborted convolution, termed the **gyrus supracallosus.** So thin is the gray coating supplied by this gyrus that the transverse direction pursued by the callosal fibres proper can be easily perceived through it.

The two extremities of the corpus callosum are much thickened, whilst the intermediate part or **body** is considerably thinner. The massive *posterior end*, which is full and rounded, lies over the mesencephalon and extends backwards as far as the highest point of the cerebellum. It is called the **splenium,** and it consists of an upper and a lower part. The latter is bent forwards under the upper part, to the inferior surface of which it is closely applied. The *anterior end* of the corpus callosum is not quite so massive and is folded downwards and backwards on itself. It is termed the **genu.** The recurved lower part of the genu is separated from the part of the corpus callosum, which lies above, by an interval. It rapidly thins as it passes backwards and receives the name of the **rostrum.** The fine terminal edge of the rostrum becomes connected with the lamina cinerea.

The gyrus supracallosus, with its contained medial and lateral longitudinal striæ, when traced backwards, is seen to turn round the splenium and become continuous with the gyrus dentatus. In front the mesial striæ, with the associated gray matter, are carried round the genu and then backwards on the under surface of the rostrum. As they turn round the anterior extremity of the corpus callosum, each stria runs into the corresponding **gyrus subcallosus**—a narrow cortical strip which lies on the mesial surface of the hemisphere immediately below the genu of the corpus callosum. The gyrus subcallosus is often called the peduncle of the corpus callosum, and the fibres of the stria which it contains, emerging from its substance, proceed backwards and outwards along the posterior limit of the anterior perforated spot towards the anterior extremity of the temporal lobe. Elliot Smith has shown that these parts have an important morphological significance.

The *under surface* of the corpus callosum on either side of the mesial plane is for the most part free, and, lined by ependyma, it forms the roof of the anterior horn and body of the lateral ventricle. In the mesial plane, however, it is attached to subjacent parts, viz. to the septum lucidum in front and to the body of the fornix behind.

The transverse fibres of the corpus callosum, as they enter the white medullary centre of the cerebral hemisphere, radiate from each other so as to reach every part of the cerebral cortex. This radiation is termed the **radiatio corporis callosi** and the fibres which compose it intersect the fibres which form the corona radiata, or, in other words, the fibres which extend between the internal capsule and the cerebral cortex (Figs. 440, p. 547; and 468, p. 582). The more anterior of the fibres which compose the genu of the corpus callosum sweep forwards in a series of curves into the prefrontal region of the hemisphere. A large part of the splenium, forming a solid bundle termed the **forceps major,** bends suddenly and abruptly backwards into the occipital lobe (Fig. 463, p. 577). Fibres from the body and upper part of the splenium, curving round the lateral ventricle, form a very definite stratum, called the **tapetum.** This is a thin layer in the medullary centre of the hemisphere, which constitutes the immediate roof and outer wall of the posterior horn and the outer wall of the hinder part of the descending horn of the lateral ventricle. In coronal sections through the occipital and hinder temporal regions the tapetum stands out very distinctly (Figs. 456, p. 569; 462, p. 576; and 465, p. 579).

Fornix.—The fornix is an arched bilateral structure composed, for the most part, of longitudinally-directed fibres. In its intermediate part its two lateral

halves are joined together in the mesial plane, and form what is called the body of the fornix; but in front and behind they are quite separate, and constitute the anterior and posterior pillars of the fornix.

The **body of the fornix** is triangular in form. In front, where it is continuous with the anterior pillars, it is narrow; whilst behind it broadens out, becomes flattened, and is finally prolonged into the posterior pillars. The upper surface of the body of the fornix is in contact with the under surface of the hinder part of the body of the corpus callosum, and posteriorly is adherent to it. In front of this adhesion, and in the mesial plane, it is attached to the septum lucidum. Beyond these attachments, on each side, the upper surface of the body of the fornix forms a part of the floor of the lateral ventricle and is clothed by the lining ependyma. It presents a sharp lateral edge or margin, from under which the choroid plexus projects into the cavity of the lateral ventricle and with which the epithelial layer which covers that plexus is continuous. The lower surface of the body of the fornix rests upon the velum interpositum, which separates it from the roof of the third ventricle and the upper surface of the optic thalami. It is not at all an uncommon occurrence to find the two lateral portions of the body of the fornix of unequal size (Fig. 461, p. 575).

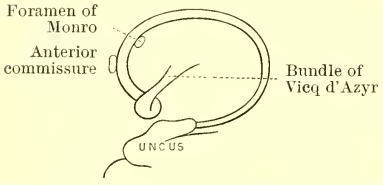


Fig. 458.—Diagrammatic Profile View of the Fornix.

The **anterior pillars of the fornix** (columnæ fornicis) are two rounded strands which emerge from the anterior part of the body of the fornix, and then diverge very slightly from each other as they curve downwards in front of the foramina of Monro. Sinking into the gray matter on the lateral wall of the third ventricle, each anterior pillar proceeds downwards to the base of the brain, and in the interpeduncular space protrudes, to take part in the formation of the corpus mammillare. When the corpus mammillare is dissected it appears to be largely formed of a twisted loop of the anterior pillar of the fornix, in which the pillar bends upon itself, and is then continued upwards and backwards into the optic thalamus. This appearance, however, is misleading. The fibres of the anterior pillar end in the gray nucleus of the corpus mammillare, and the strand which passes from this to the thalamus is the **bundle of Vicq d'Azyr** (p. 548).

The **posterior pillars of the fornix** (crura fornicis) are flattened bands which diverge widely from each other. At first they are adherent to the under surface of the corpus callosum, but soon they sweep downwards round the posterior ends of the optic thalami and enter the descending horns of the lateral ventricles. Here each pillar comes into relation with the corresponding hippocampus major, and a portion of its fibres are spread out on the surface of this prominence, thereby giving it a white coating termed the **alveus**, whilst the remainder of the fibres constitute the **fimbria** or **tænia fornicis**—a narrow but very distinct band of white matter, which is attached by its outer margin along the inner border of the hippocampus major and ends in front by joining the uncus (p. 568).

A certain number of transverse fibres enter into the formation of the fornix. The diverging posterior pillars enclose between them a small triangular space on the under surface of the hinder part of the corpus callosum. This area is crossed by transverse fibres, which form a thin lamina called the **psalterium** or **lyra.** Sometimes the psalterium is not completely fused to the under surface of the corpus callosum, and in these cases a narrow space is left between them, which receives the name of **Verga's ventricle.**

The fornix is intimately connected with the olfactory apparatus. Its fibres for the most part, arise from the pyramidal cells in the cornu ammonis or hippocampus major and ascend in the fimbria and posterior pillar. In the region of the psalterium numerous fibres cross the mesial plane, enter the opposite posterior pillar, and in it proceed to the opposite cornu ammonis. These fibres constitute a commissure between the two cornua ammonis. The remainder of the fibres proceed forwards in the body of the fornix, and by means of the anterior pillar the majority of the fibres are carried downwards, behind the anterior commissure, to the corpus mammillare. Some, however, curve backwards into the stria medullaris (p. 548); whilst others, forming the **olfactory bundle of the cornu ammonis,** pass in front of the anterior commissure and

enter the septum lucidum, through which they reach the subcallosal gyrus and the locus perforatus anticus. Finally, this bundle divides into two parts, of which one joins the inner root of the olfactory tract, whilst the other goes to the uncus.

The greater number of the longitudinal fibres of the fornix must, therefore, be regarded as establishing a connexion between the cornu ammonis and the optic thalamus. The inner portion of the composite nucleus of the corpus mammillare is an internode interposed in the path of this connecting tract. The bundle of Vicq d'Azyr, formed by the relay of fibres which takes origin in this internode, forms the second link in the chain.

The striæ longitudinales in the gyrus supracallosus on the upper surface of the corpus callosum are to be regarded, from a morphological point of view, as forming an outlying part of the fornix system.

There can be little doubt that the gyrus supracallosus represents a wasted portion of the hippocampus formation. In monotremes and marsupials the hippocampus occupies a corresponding position, but, with the greater development of the corpus callosum in higher mammals, atrophy and stretching occur and the structure is reduced to a vestigial condition (Elliot Smith). That fornix fibres therefore should be found in connexion with the supracallosal gyrus is not surprising.

Septum Lucidum (septum pellucidum).—The septum lucidum is a thin vertical partition which intervenes between the anterior cornua and foreparts of the bodies of the two lateral ventricles. It is triangular in shape, and posteriorly it is prolonged backwards for a variable distance between the body of the corpus callosum and the fornix, to both of which it is attached by its upper and lower edges. In front it occupies the gap behind the genu of the corpus callosum, whilst below, in the narrow interval between the posterior edge of the rostrum of the corpus callosum and the fornix, it is prolonged downwards towards the base of the brain in the gyrus subcallosus. The septum lucidum is composed of two thin laminæ in apposition with each other in the mesial plane (Fig. 461, p. 575).

Fifth Ventricle (cavum septi pellucidi).—This name is applied to the mesial cleft between the two laminæ of the septum lucidum. It varies greatly in size in different brains and contains a little fluid. It is completely isolated and presents no communication with the other ventricles of the brain. Indeed, the term "ventricle," as applied to it, is quite inappropriate, seeing that at no period in the development of the brain has it any connexion with the general ventricular system.

Lateral Ventricle.

The cavity in the interior of the cerebral hemisphere is called the lateral ventricle. It is lined throughout by ependyma continuous with the ependymal lining of the third ventricle. In many places the walls of the cavity are in apposition, whilst in other localities spaces of varying capacity, and containing cerebrospinal fluid, are left between the bounding walls.

The **lateral ventricle** (ventriculus lateralis) communicates with the third ventricle of the brain by means of a small foramen, just large enough to admit a crow-quill, which is termed the **foramen of Monro**. This aperture is placed in front of the fore end of the optic thalamus and behind the anterior pillar of the fornix.

The highly-irregular shape of the lateral ventricle can be best understood by the study of a cast of its interior (Figs. 459; and 444, p. 551). It is usual to describe it as being composed of a body and three horns, viz. an anterior, a posterior, and a descending horn. The **anterior horn** is that part of the cavity which lies in front of the foramen of Monro. The **body** is the portion of the ventricle which extends from the foramen of Monro to the splenium of the corpus callosum. At this point the posterior and descending horns diverge from the hinder part of the body. The **posterior horn** curves backwards and inwards into the occipital lobe. It is very variable in its length and capacity. The **descending horn** proceeds with a bold sweep round the hinder end of the optic thalamus, and then tunnels in a forward and inward direction through the temporal lobe towards the temporal pole. The early fœtal lateral ventricle is very capacious and presents an arched or semilunar form. It is composed of parts which correspond to the anterior horn, the body, and the descending horn, and there is little or no demarcation between them. The posterior horn is a later production. It comes into existence with the occipital lobe and is produced as a diverticulum or elongated pouch, which grows backwards from the upper and hinder part (*i.e.* the convexity) of the primitive cavity.

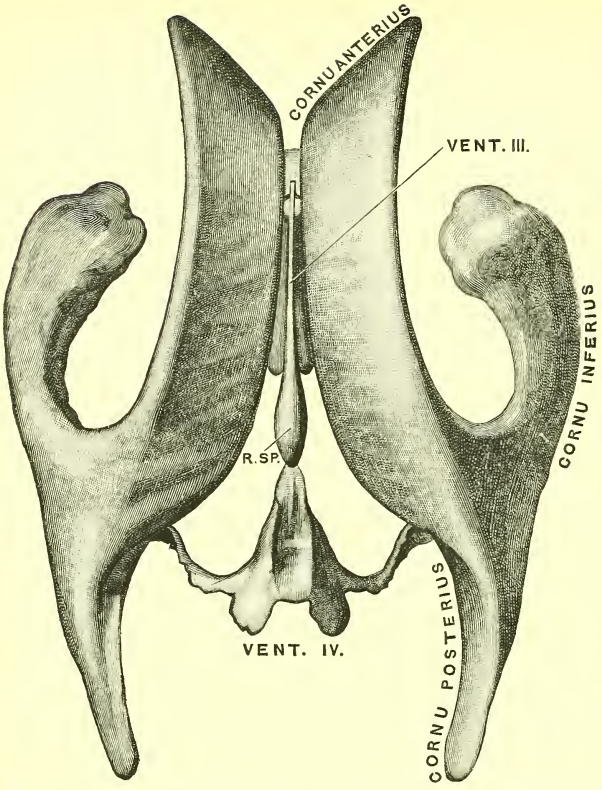


FIG. 459.—DRAWING TAKEN FROM A CAST OF THE VENTRICULAR SYSTEM OF THE BRAIN, as seen from above (after Retzius).

Vent. III. Third ventricle. Vent. IV. Fourth ventricle.
R.SP. Recessus suprapinealis.

Anterior Horn of the Lateral Ventricle (cornu anterius). — The anterior horn forms the foremost part of the cavity, and extends in a forward and outward direction in the frontal lobe. When seen in coronal section (Fig. 460) it presents a triangular outline, the floor sloping upwards and outwards to meet the roof at an acute angle. It is bounded *in front* by the posterior surface of the genu of the corpus callosum; the *roof* is also formed by the corpus callosum. The *inner wall*, which is vertical, is formed by the septum lucidum; whilst the sloping *floor* presents a marked elevation or bulging, viz. the smooth, rounded, and prominent extremity of the pear-shaped caudate nucleus.

Body of the Lateral Ventricle (pars centralis).—The body of the cavity is likewise *roofed* by the corpus callosum. On the *inner* or *mesial side* it is bounded by the attachment of the fornix to the under surface of the corpus callosum and by the hinder part of the septum lucidum. On the *outer side* it is closed, as in the case of the anterior horn, by the meeting of the floor and the roof of the cavity. On the *floor* a number of important objects may be recognised. From without inwards these are met in the following order: (1) the caudate nucleus; (2) a groove which extends obliquely from before backwards and outwards between the caudate nucleus and the optic thalamus, and in which are placed the vein of the corpus striatum and a white band called the tænia semicircularis; (3) a portion of the upper surface of

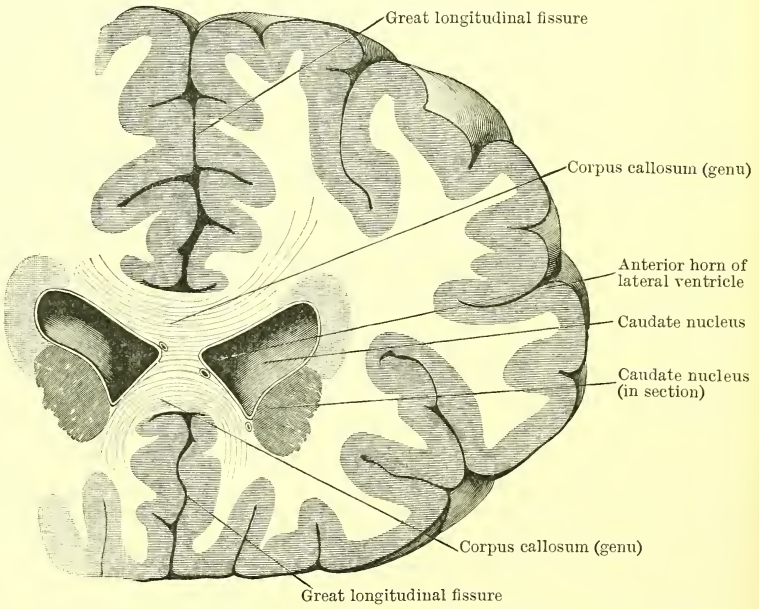


FIG. 460.—CORONAL SECTION THROUGH THE FRONTAL LOBES AND THE ANTERIOR HORNS OF THE LATERAL VENTRICLES.

the optic thalamus; (4) the choroid plexus; (5) the thin, sharp lateral edge of the fornix.

The **caudate nucleus** narrows rapidly as it proceeds backwards on the outer part of the floor of the body of the lateral ventricle. The **vein of the corpus striatum** is covered over by ependyma. It joins the vein of Galen close to the foramen of Monro. The connexions of the **tænia semicircularis** will be dealt with later. The portion of the upper surface of the **optic thalamus** which appears in the floor of the

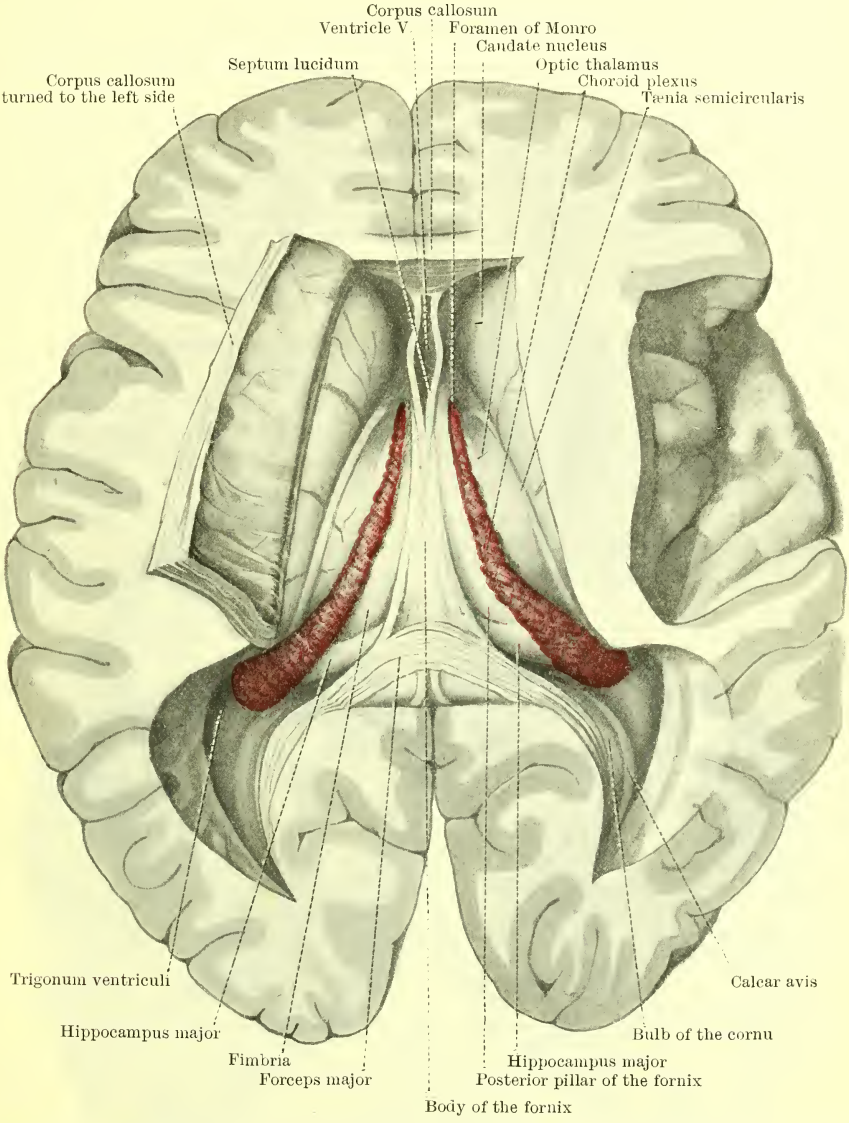


FIG. 461.—DISSECTION, to show the fornix and lateral ventricles; the body of the corpus callosum has been turned over to the left.

ventricle is in great part hidden by the choroid plexus, which lies upon it. The **choroid plexus** is a rich vascular fringe which appears from under cover of the sharp lateral edge of the fornix. In front it is continuous, behind the foramen of Monro, with the corresponding choroid plexus of the opposite side, whilst behind, it is carried into the descending horn of the ventricle. Although the choroid plexus has all the appearance of lying free within the ventricle, it must be borne in mind that it is invested by an epithelial layer which represents a portion of the hemisphere wall and excludes it from the cavity. This thin layer is continuous on the

one hand with the sharp edge of the fornix, and on the other it is attached to the upper surface of the optic thalamus.

Posterior Horn of the Lateral Ventricle (cornu posterius).—The posterior horn is an elongated diverticulum carried backwards into the occipital lobe from the hinder end of the body of the ventricle. It tapers to a point and describes a gentle curve, the convexity of which is directed outwards. The *roof* and *outer wall* of this portion of the ventricular cavity are formed by the tapetum of the corpus callosum. In coronal sections through the occipital lobe this is seen as a thin but distinct layer of white fibres, which lies immediately outside the ependyma and to the inner side of a much larger strand of fibres in the medullary substance of the occipital lobe, viz. the optic radiation.

On the *inner wall* two elongated curved elevations may be observed. The uppermost of these is termed the **bulb of the cornu** (bulbus cornu posterioris), and is produced by the fibres of the forceps major of the corpus callosum as they curve abruptly backwards from the lower part of the splenium of the corpus callosum into the occipital lobe. Below this is the elevation known as the **calcar avis**. It varies greatly in size in different brains, and is caused by an infolding of the ventricular wall in correspondence with the anterior calcarine fissure on the exterior of the hemisphere.

Descending Horn of the Lateral Ventricle (cornu inferius).—The descending horn is the continuation of the cavity into the temporal lobe. At first directed backwards and outwards the descending horn suddenly sinks downwards behind the optic thalamus into the temporal lobe, in the centre of which it takes a curved course forwards and inwards to a point about an inch behind the extremity of the temporal pole.

In the angle between the diverging posterior and descending horns the cavity of the ventricle presents an expansion of a somewhat triangular shape. To this the name of **trigonum ventriculi** is sometimes given.

The *roof* of the descending horn is formed for the most part by the tapetum of

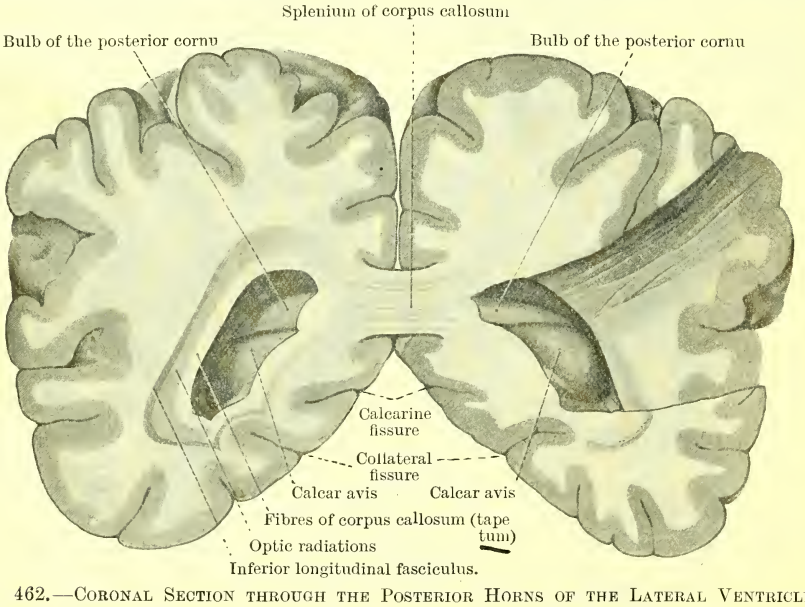


FIG. 462.—CORONAL SECTION THROUGH THE POSTERIOR HORNS OF THE LATERAL VENTRICLES.

the corpus callosum. At the extremity of the horn the roof presents a bulging into the cavity. This is the **amygdaloid tubercle**, and it is produced by a superjacent collection of gray matter termed the amygdaloid nucleus. The **tænia semicircularis** and the attenuated **tail of the caudate nucleus** are both prolonged into the descending horn and are carried forwards, in its roof, to the amygdaloid nucleus.

On *the floor* of the descending horn the following structures are seen: (1) hippocampus major, or the cornu ammonis; (2) the choroid plexus; (3) the fimbria; and (4) the eminentia collateralis.

The **hippocampus major** (hippocampus) is for the most part covered by the

choroid plexus. It is a prominent elevation on the floor of the descending horn of the lateral ventricle and is strongly curved, in conformity with the course taken by the horn in which it lies. It therefore presents an internal concave margin and an external convex border. Narrow behind, it enlarges as it is traced forwards, and it ends below the amygdaloid tubercle in a thickened extremity, which presents some faint grooves or notches on its surface. In consequence of this, the anterior end of the hippocampus major receives the name of the **pes hippocampi.** The hippocampus major is the internal elevation which corresponds to the dentate fissure on the exterior of the hemisphere (Fig. 464).

If an incision be made along the outer convex edge of the hippocampus major, and the surface lamina be raised, the central core will be seen to present the curious appearance of two corrugated layers dove-tailed into each other (M'Carthy).

The **fimbria** (fimbria hippocampi) is the narrow band of white matter which is attached by its outer margin along the inner concave border of the hippocampus major. The white matter composing it is continuous with the thin white layer (the alveus) which is spread over the surface of the hippocampus major, and it presents two free surfaces and a sharp free inner border. The fimbria has already been examined in connexion with the hippocampal fissure and the gyrus dentatus

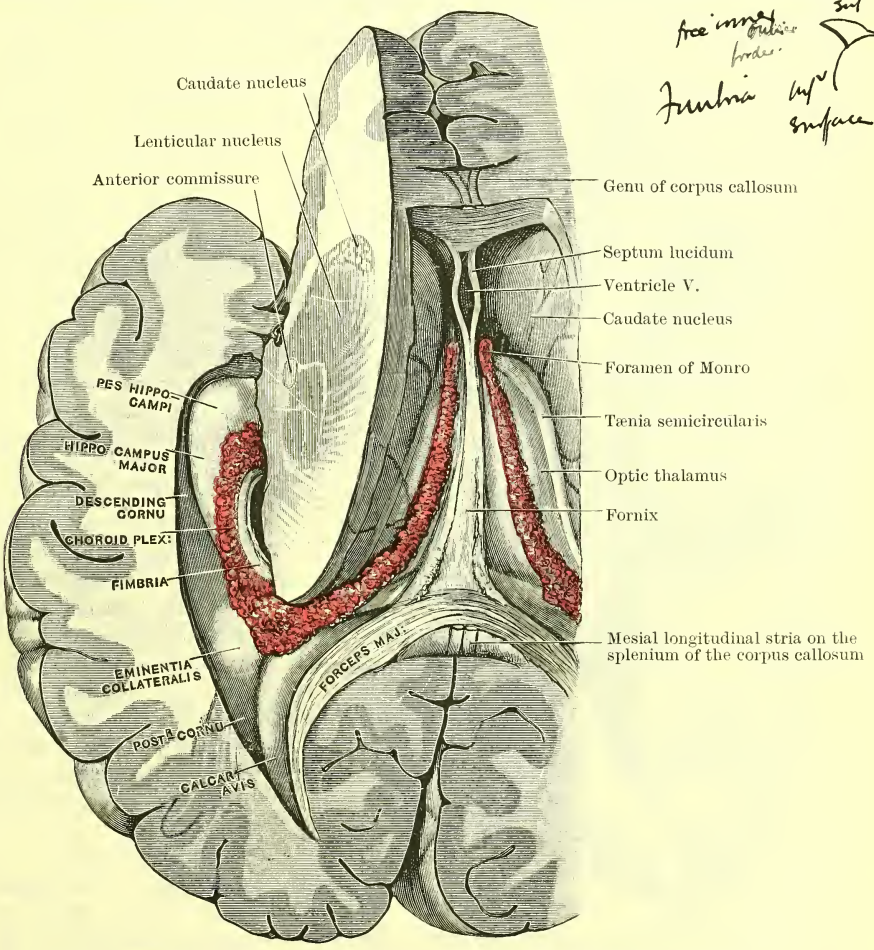


FIG. 463.—DISSECTION, to show the fornix and the posterior and descending cornua of the lateral ventricle of the left side.

(p. 568), and the relations which it presents to the fornix and the uncus have been pointed out.

When the pia mater in the region of the hippocampal fissure is removed from the surface of the brain, the choroid plexus in the interior of the descending horn

of the lateral ventricle is usually withdrawn with it, and a fissure appears between the fimbria and the roof of the ventricular horn. This is the **choroid fissure.** It appears at a very early date in the development of the cerebral hemisphere, and takes an arcuate course upwards and forwards round the hinder end of the optic thalamus. In the region of the body of the lateral ventricle it extends as far forwards as the foramen of Monro, and is formed by the involution of an epithelial part of the wall of the ventricle over the choroid plexus (p. 575). In the region of the descending horn, when the choroid plexus with the involuted epithelial layer which covers it is withdrawn, the choroid fissure is converted into an artificial gap which leads directly into this part of the ventricular cavity.

The **choroid plexus** is a convoluted system of blood-vessels in connexion with a fold of pia mater, which is prolonged into the descending horn of the lateral ventricle. It lies on the surface of the hippocampus major and is continuous behind the posterior part of the optic thalamus, with the choroid plexus in the body of the lateral ventricle. But it must not be supposed that the choroid plexus lies free in the ventricular cavity. It is clothed in the most intimate manner by an epithelial layer, which represents the inner or mesial wall of the descending horn involuted into the cavity over the choroid plexus. The ventricle, therefore, only opens on the surface through the choroid fissure when this thin epithelial layer is torn away by the withdrawal of the choroid plexus. From the above, it will be understood that the arcuate choroid fissure, throughout its whole length (viz. from the foramen of Monro to the extremity of the descending horn of the lateral ventricle), is formed by the involution of a portion of the wall of the hemisphere which remains epithelial. In the body of the ventricle this layer is attached, on the one hand, to the sharp lateral margin of the fornix, and on the other to the upper surface of the optic thalamus; in the descending horn it is attached, in like manner, to the edge of the fimbria or posterior pillar of the fornix, whilst above it joins the roof of this portion of the ventricle along the line of the tænia semicircularis.

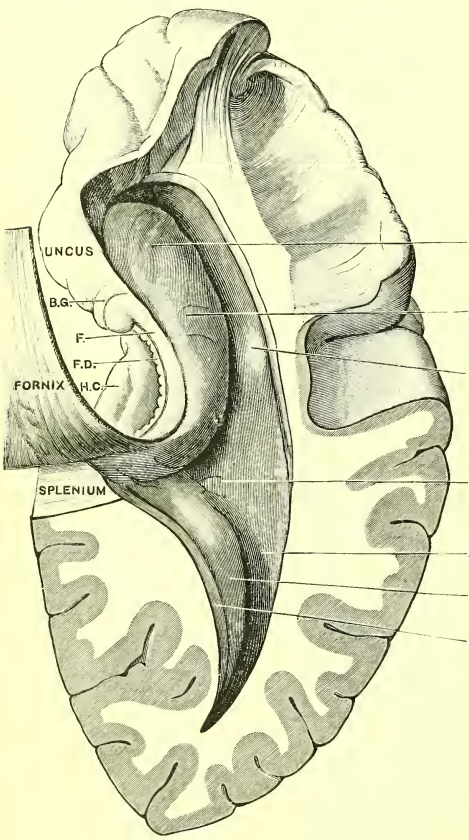


FIG. 464.—DISSECTION from above, to show the posterior and descending cornua of the lateral ventricle.

B.G. Giacomini's band. F.D. Gyrus dentatus.
F. Fimbria. H.C. Hippocampal convolution.

The **eminentia collateralis** shows very great differences in its degree of development, and it may present two distinct forms, which may be distinguished from each other as the eminentia collateralis posterior and the eminentia collateralis anterior.

The *posterior collateral eminence* is a smooth elevation in the floor of the trigonum ventriculi, in the interval which is left between the calcar avis and the hippocampus major as they diverge from each other. In the fœtal brain this is always a very strongly-marked elevation, which corresponds with the mid-collateral fissure, but in the course of growth it is apt to lose much of its prominence.

The *anterior collateral eminence* is only occasionally present. It appears as an elongated elevation of varying length and prominence, on the floor of the descending horn of the lateral ventricle, on the outer side of the hippocampus major. It is formed by the anterior portion of the fœtal collateral sulcus, when this develops as a complete fissure.

Basal Ganglia of the Cerebral Hemisphere.

Under this heading are included certain masses of gray matter more or less completely embedded in the white medullary substance of the hemisphere, and which are developed in its wall. They compose the caudate and lenticular nuclei, which together form the corpus striatum, the claustrum, and the amygdaloid nucleus.

The **caudate nucleus** bulges into the lateral ventricle. It is a pyriform, highly-arched mass of gray matter, which presents a thick, swollen head, or anterior extremity, and a long, attenuated tail. The head projects into the anterior horn of the lateral ventricle, whilst its narrower part is prolonged outwards and backwards in the floor of the body of the ventricle, where it is separated from the optic thalamus by the tænia semicircularis. Finally, its tail curves downwards with a bold sweep and enters the descending horn of the lateral ventricle. In the roof of this horn it is prolonged forwards to the amygdaloid nucleus, the lower part of which it joins. The caudate nucleus thus presents a free ventricular surface, covered with ependyma, and a deep surface embedded in the white substance of the cerebral hemisphere, and for the most part related to the internal capsule.

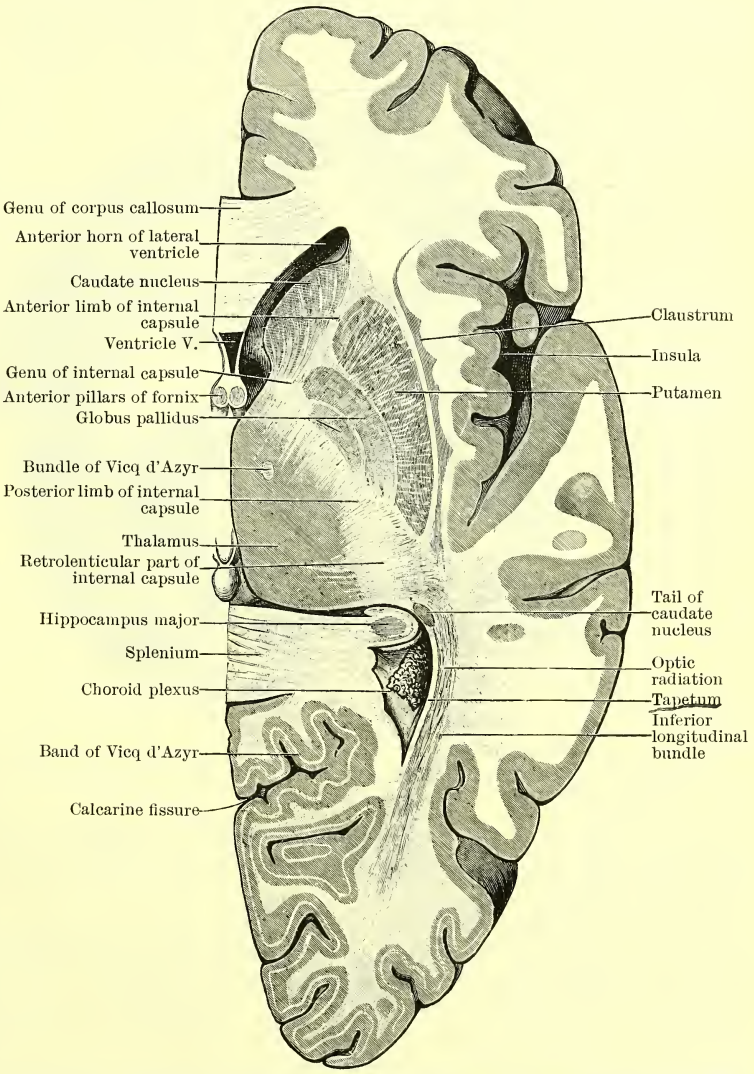


Fig. 465.—Horizontal Section through the Right Cerebral Hemisphere at the Level of the Widest Part of the Lenticular Nucleus.

Owing to its arched form it follows that, in horizontal sections through the cerebral hemisphere below a particular level, it is cut at two points, and both the head and the tail appear on the field of the section (Fig. 465). In coronal sections behind the amygdaloid nucleus, it is also divided at two places (Fig. 440, p. 547).

The anterior extremity of the head of the caudate nucleus coincides very nearly with that of the anterior horn of the lateral ventricle. In the region of the locus perforatus anticus, the head of the caudate nucleus gains the surface and its gray matter becomes continuous with that of the cerebral cortex.

The **lenticular nucleus** lies on the outer side of the caudate nucleus and optic thalamus, and is for the most part embedded within the white medullary substance of the cerebral hemisphere. It does not extend either so far forwards or so far backwards as the caudate nucleus. Indeed, it presents a very close correspondence in point of extent with the insula or island of Reil on the surface. When seen in horizontal section, it presents a shape similar to that of a biconvex lens. Its inner surface bulges more than the outer surface, and its point of highest convexity is placed opposite the tænia semicircularis or the interval between the caudate nucleus and the optic thalamus. In coronal section the appearance presented by the lenticular nucleus differs very much in different planes of section. Fig. 466 represents a section through its anterior portion. Here it is semilunar or crescentic in outline and is directly continuous below with the head of the caudate nucleus; above, also, it is intimately connected with the caudate nucleus by bands of gray matter, which pass between the two nuclei and break up the white matter of the forepart of the intervening internal capsule. It is due to the ribbed or barred appearance, which is presented by such a section as this, that the term **corpus striatum** is applied to the two nuclei. In the region of the locus perforatus anticus both nuclei reach the surface and become continuous with the cortex.

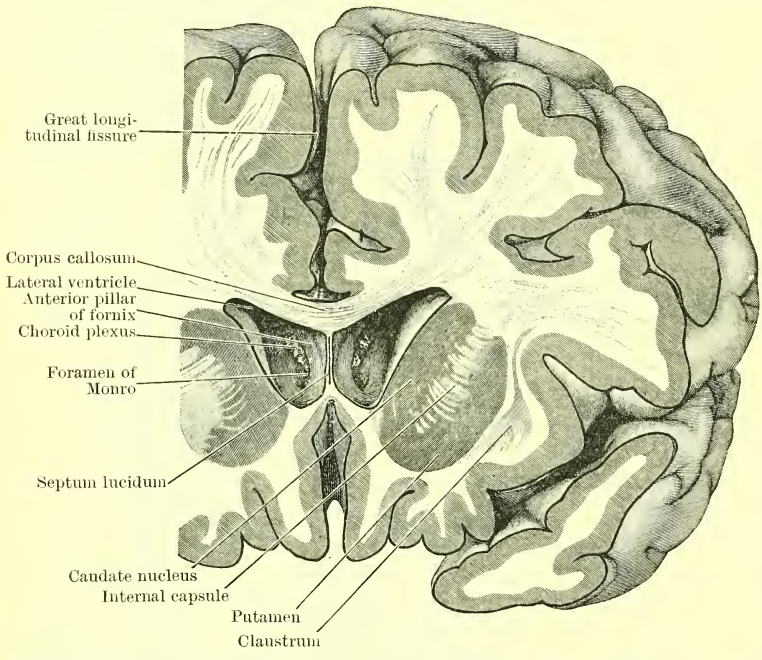


FIG. 466.—CORONAL SECTION THROUGH THE CEREBRAL HEMISPHERES so as to cut through the anterior part (putamen) of the lenticular nucleus in front of the globus pallidus.

When a section is made in a plane further back (*e.g.* immediately posterior to the anterior commissure, as in Fig. 467) the divided lenticular nucleus assumes an altogether different shape, and is seen to be completely cut off from the caudate nucleus by the internal capsule. It is now triangular or wedge-shaped. Its *base* is turned towards the island of Reil and is in direct relation to a thin lamina of white matter, termed the external capsule. Its *internal surface* is oblique and is applied to the internal capsule, whilst its *inferior surface* is horizontal and is directed downwards towards the base of the brain. But, further, two white laminæ, the **external** and **internal medullary laminæ**, are now evident, which traverse its substance in a vertical direction and divide it into three zones. The outer, basal, and larger zone is termed the **putamen**; the two inner portions together constitute the **globus pallidus.**

The **putamen** forms much the largest part of the lenticular nucleus. It is darker in colour than the globus pallidus, and in this respect resembles the caudate nucleus. It is traversed by fine radiating bundles of fibres, which enter it from the

external medullary lamina. Both in point of structure and in mode of development it is closely associated with the caudate nucleus, and it is the only part of the lenticular nucleus which is connected by intervening bands of gray matter with the caudate nucleus. The antero-posterior length, as well as the vertical depth of the putamen, is much greater than in the case of the globus pallidus; consequently, in

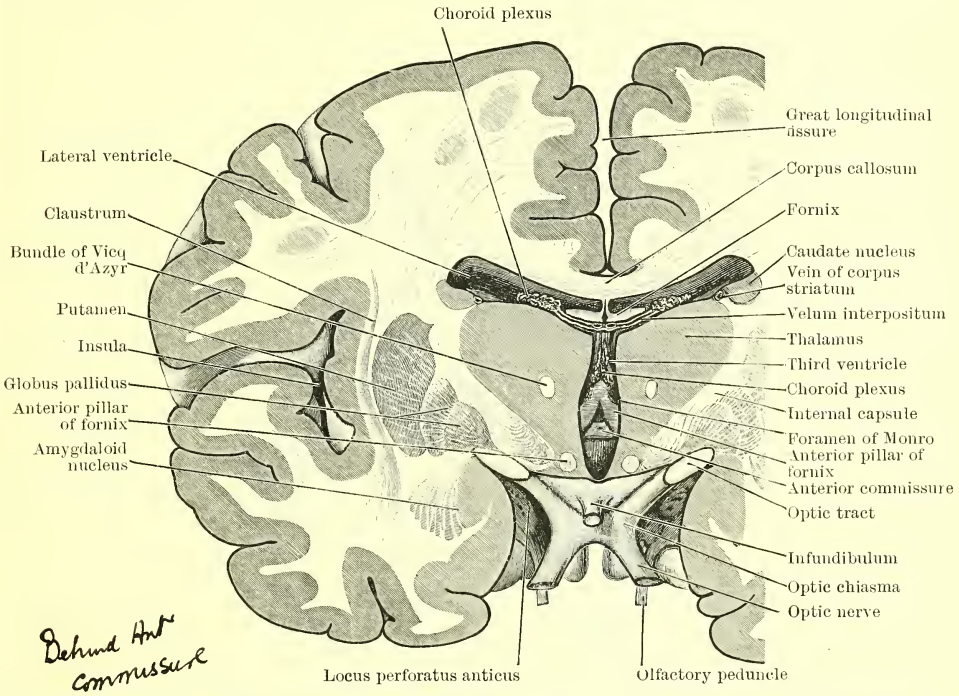


FIG. 467.—CORONAL SECTION THROUGH THE CEREBRUM so as to cut through the three divisions of the lenticular nucleus; posterior surface of the section depicted.

both coronal and horizontal sections through the cerebrum it is encountered before the plane of the globus pallidus is reached.

The external capsule is loosely connected with the outer surface of the putamen, and it can be readily stripped off. This accounts for the tendency, exhibited in hæmorrhages in this locality, for the effused blood to spread out in the interval between these structures.

The **globus pallidus** is composed of the two smaller and inner zones of the lenticular nucleus. They present a faint yellowish tint, and are paler and more abundantly traversed by fibres than the putamen. The zone next the putamen (*i.e.* the intermediate zone) is much larger than the innermost subdivision. It extends forwards to a point a little in front of the plane of the anterior commissure. When the lenticular nucleus is cut in a coronal direction, and in its widest part, the innermost zone shows an indication of a separation into two parts, so that here the globus pallidus appears to consist of three subdivisions. The morphology of the globus pallidus is by no means clear.

Connexions of the Corpus Striatum.—(1) Numerous fibres pass from the optic thalamus to the corpus striatum, and in the reverse direction from the corpus striatum into the thalamus through the anterior limb of the internal capsule. These may be termed the **thalamo-striate** and the **strio-thalamic fibres**. (2) Edinger describes a connexion between the caudate nucleus and the substantia nigra. The connecting fibres pass through the subthalamic region and constitute a tract in the mesencephalon, in close apposition with the substantia nigra, called the **stratum intermedium**. (3) The **ansa lenticularis** has previously been mentioned. It is composed of fibres which come from the inferior part of the fore portion of the thalamus and curve outwards under the lenticular nucleus. They stream upwards into this and through its medullary laminæ. Many of them apparently proceed onwards to the cerebral cortex. (4) Fibres from the posterior

limb of the internal capsule (thalamic fibres chiefly) enter the lenticular nucleus and stream through it, and its medullary laminæ, on their way to the cerebral cortex.

Claustrum.—This is a thin plate of gray substance embedded in the white matter, which intervenes between the lenticular nucleus and the gray cortex of the insula or island of Reil. Followed in an upward direction, it becomes gradually thinner and ultimately disappears. As it is traced downwards, however, it

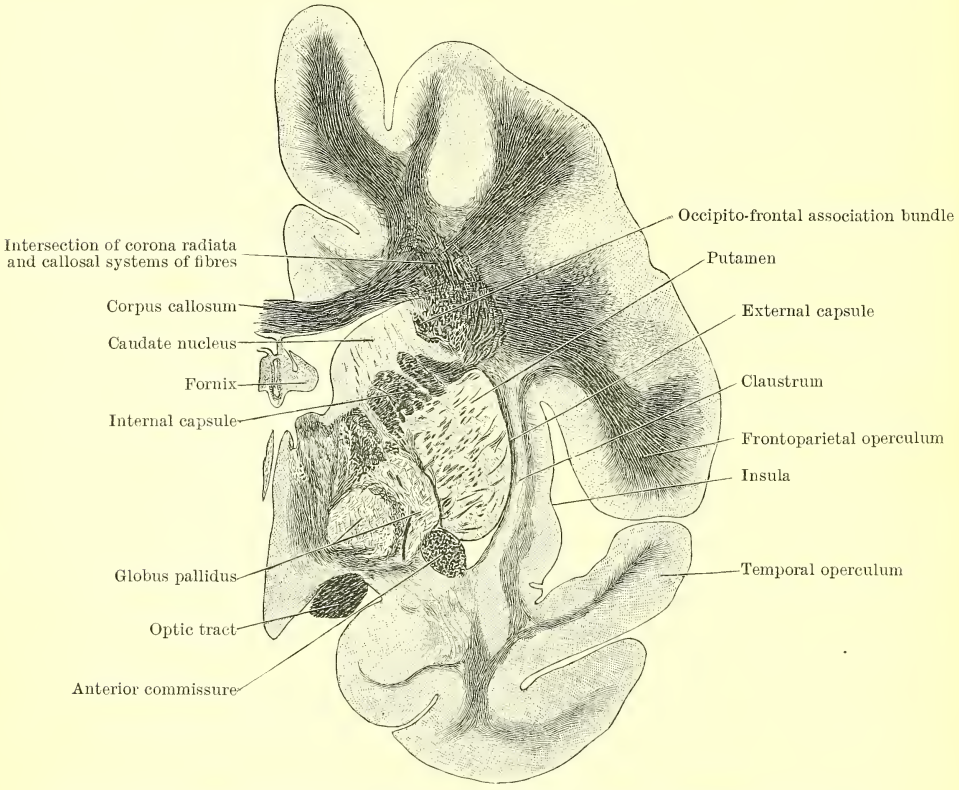


Fig. 468.—Coronal Section through the Left Side of the Cerebrum of an Orang (Weigert-Pal specimen).

The section passes through the middle of the lenticular nucleus.

thickens considerably, and at the base of the brain it comes to the surface at the anterior perforated spot and becomes continuous with the gray matter of the cortex. Its extent corresponds very closely with the area occupied by the insula, and its surface towards this portion of the cerebral cortex shows ridges and depressions corresponding to the insular gyri and sulci.

Amygdaloid Nucleus.—In the forepart of the temporal lobe, in front of, and to some extent above the extremity of the descending horn of the lateral ventricle, there is a round mass of gray matter, called the amygdaloid nucleus. The tail of the caudate nucleus joins its lower part, whilst above it is carried up into the putamen. In front it is continuous with the gray cortex of the cerebrum.

Tænia Semicircularis.—This is a band of fibres which, for the most part, arise in the amygdaloid nucleus. From this it runs backwards in the roof of the descending horn of the lateral ventricle, and then arches upwards and forwards, so as to gain the floor of the body of the lateral ventricle. In both situations it lies close to the inner side of the nucleus caudatus, and finally, at the foramen of Monro, it bends downwards towards the anterior commissure. Some of its fibres pass in front and others behind the commissure, and ultimately they end in the locus perforatus anticus (Kölliker).

Internal Capsule.—This term is applied to the broad band of white matter which intervenes between the lenticular nucleus, on the outside, and the optic

thalamus, tænia semicircularis, and caudate nucleus on the inner side. It presents many different appearances, according to the plane in which the brain is cut. In the region of the mesencephalon, a coronal section through the brain shows that in great part the internal capsule is directly continuous with the crusta of the crus cerebri (Fig. 440, p. 547). In horizontal section the internal capsule is observed to be bent upon itself opposite the tænia semicircularis, or the interval between the caudate nucleus and the thalamus. This bend, which points inwards, is called the **genu**. About one-third of the internal capsule lies in front of the genu, and is termed the anterior limb; the remaining two-thirds, which lie behind the genu, constitute the posterior limb.

The **anterior limb of the internal capsule** intervenes between the lenticular nucleus and the caudate nucleus. In its lower and forepart it is much broken up by the connecting bands of gray matter which pass between the forepart of the putamen and the lenticular nucleus.

The anterior limb of the internal capsule is largely composed of corticipetal fibres belonging to the thalamic radiation. It likewise contains corticifugal fibres. The *corticipetal fibres* are of two kinds, viz. thalamo-frontal and thalamo-striate. The former, which arise in the optic thalamus, go through the anterior limb of the internal capsule to reach the cortex of the frontal lobe. The thalamo-striate fibres likewise arise in the thalamus and enter the anterior limb, to reach the caudate and lenticular nuclei.

The corticifugal fibres are represented by the fronto-thalamic, the strio-thalamic, and the fronto-pontine tracts.

The **fronto-pontine tract** arises in the cortex of the prefrontal region, traverses the anterior limb of the internal capsule, forms the inner fifth of the crusta of the crus cerebri, and finally ends in the nucleus pontis.

The **posterior limb of the internal capsule** is placed between the optic thalamus and the lenticular nucleus, and it extends backwards for a short distance beyond the hinder end of the putamen on the outer side of the posterior part of the thalamus and of the tail of the caudate nucleus. The posterior limb, therefore, is spoken of as consisting of a lenticular and a retrolenticular part.

The **lenticular part** of the posterior limb is composed of both corticipetal and corticifugal fibres. The *corticipetal fibres* enter the internal capsule from the outer aspect of the optic thalamus, and are composed of fibres which arise within the thalamus, and proceed upwards to the cerebral cortex.

The *corticifugal fibres* consist of the pyramidal tract and the cortico-thalamic fibres.

The great **motor** or **pyramidal tract**, descending from the Rolandic area of the cortex, occupies the anterior half of the lenticular part of the internal capsule. The fibres, which go to the nucleus of the facial nerve, lie close to the genu, and behind these are the fibres which go to the hypoglossal nucleus; still further back are pyramidal fibres which enter the spinal cord and end around the motor cells of the anterior horn of gray matter. This pyramidal tract has been observed occupying the middle part of the crusta of the crus cerebri, into which it passes directly from the internal capsule.

The **retrolenticular part** of the posterior limb contains: (1) the fibres of the optic radiation as they pass to establish their connexions with the thalamus, superior quadrigeminal body, and corpus geniculatum externum; (2) the fibres of the auditory radiation, or those which connect the auditory cortical field in the temporal lobe with the corpus geniculatum internum (Figs. 418, p. 520, and Fig. 439, p. 546); (3) the temporo-pontine tract, which is composed of fibres which take origin in the two upper convolutions of the temporal lobe and pass through this section of the internal capsule to reach the outer part of the crusta of the crus cerebri. Through this they reach the ventral part of the pons, in the gray matter of which they end.

When the fibres of the internal capsule are traced upwards they are found to spread out widely from each other in a radiating or fan-shaped manner, so as to reach the various convolutions of the cerebral hemisphere. This arrangement is termed the **corona radiata**. The callosal system of fibres, as they proceed into the hemisphere, also radiate, and they intersect the fibres of the corona radiata (Fig. 468, p. 582).

External Capsule.—The thin lamina of white matter between the outer aspect of the putamen and the claustrum is called the external capsule. This joins with

the internal capsule in front of and behind the putamen, and in this manner the lenticular nucleus is encapsulated by white matter.

Morphological Subdivision of the Cerebral Hemisphere.—In many respects the descriptive anatomy of the human cerebral hemisphere is not in accord with the facts which have been acquired regarding its morphological evolution; and of recent years this discrepancy has become more marked through the important researches of Elliot Smith.

From the morphological point of view the cerebral hemisphere may be regarded as being composed of three parts, viz. the rhinencephalon, the corpus striatum, and the neo-pallium.

The **rhinencephalon** is the most archaic part of the hemisphere, and in the brains of the lower vertebrates (fishes, amphibians, reptiles) it constitutes its chief bulk. In the human brain it is represented by the olfactory bulb, olfactory tract and its roots, the anterior perforated space, the uncus, the gyrus subcallosus, the septum lucidum, the hippocampus, fornix, gyrus dentatus, and the gyrus supracallosus.

The uncus, with the aborted lateral stria of the olfactory peduncle, is all that remains in the human brain of the relatively huge pyriform lobe of many of the lower mammals. The hippocampal convolution which lies to the outer side of the dentate fissure, although it runs continuously into the uncus, is not a part of the rhinencephalon. It belongs to the neo-pallium. The feeble furrow, termed the incisura temporalis which separates the uncus from the temporal pole, is one of the most primitive of the cerebral fissures. It represents the rhinal or ecto-rhinal fissure—the bounding fissure of the rhinencephalon.

The **neo-pallium** is represented by the rest of the hemisphere, exclusive of the corpus striatum. It therefore comprises almost the whole of the convoluted cortex on the surface together with its associated white matter. The great development of the neo-pallium in man is one of the most distinctive characters of the human brain.

In their phylogenetic evolution the rhinencephalon and the neo-pallium appear to develop more or less independently of each other. In certain cases the former atrophies, whilst the neo-pallium attains a high degree of development (*e.g.* man, monkey, whale, etc.), in others the reverse development occurs (*e.g.* hedgehog and many other mammals), in which the rhinencephalon forms a large part of the hemisphere and the neo-pallium is relatively small.

Intimate Structure of the Cerebral Hemisphere.

The cerebral hemisphere is composed of an external coating of gray matter, termed the **cortex**, spread over an internal mass of white matter, which is called the **medullary centre.** The cortex is of peculiar interest, seeing that there is good reason for believing that in it the higher functions of the brain, or those which may be classed under the general designation of the intellectual functions, take place. It is within the same layer of gray matter that the influence of those external impressions, which gain access to the cerebro-spinal axis through the senses, finally take shape as consciousness; and in it also are placed the centres which carry on the psycho-motor functions. The white medullary centre is composed of nerve-fibres which constitute the paths along which the influence of impressions is carried to and from the cortex, and from one part of the cortex to another.

The Cerebral Cortex.

The gray cortex is spread over the entire surface of the cerebral hemisphere, but it does not form a layer of equal thickness in all localities. At the summit of a convolution it is always thicker than at the bottom of a furrow. The maximum thickness of cortex (about 6 mm.) is attained in the upper parts of the two central convolutions, whilst the minimum (about 2·5 mm.) may be observed in the region of the occipital pole. The amount of gray cortex differs considerably in different individuals, and appreciably diminishes in old age. It is also stated, but upon imperfect evidence, that it is relatively more abundant in the male than in the female.

In structure, likewise, marked differences may be noted in the gray cortex of different regions, and excellent work has been recently done in the direction of connecting these structural peculiarities with the functional characteristics of particular areas and applying them to the determination of morphological problems connected with the cerebral surface (Campbell and Bolton). In certain localities this structural difference is quite apparent to the naked eye when sections are made through the cortex. There are, however, no sharp transitions in structure. One form of cortex passes, as a rule gradually and almost insensibly, into the variety of cortex which is distinctive of an adjoining region, and throughout the whole

mass a general ground type may be recognised. It is only to those general structural features which more or less characterise the entire cortical layer that we shall be able to refer.

When sections are made through the fresh brain, and the cut surface is closely inspected, it will usually be apparent that the cortex is indistinctly stratified. On the outside there is a thin, whitish layer, and beneath this the gray matter presents two strata of very nearly equal thickness, viz. a middle, gray-coloured stratum and an inner, yellowish-red stratum. Between the two latter layers a narrow white band is, in many places, visible. This is termed the **outer band of Baillarger**. When the layers indicated above are present, four strata superimposed on each other are recognised; but in certain regions, as, for instance, in the anterior central convolution, a second white streak traverses the deep or inner gray layer and divides it into two. This is termed the **inner white band of Baillarger**, and, when it is present, the gray cortex becomes divided obscurely into six alternating white and gray layers.

The outer band of Baillarger is strongly marked in the region of the calcarine fissure and gives a characteristic appearance to this portion of the cortex. In this locality it receives the name of the **band of Vicq d'Azyr** or the **stria of Gennari** (Fig. 465, p. 579).

According to Henschen the visual centre is strictly limited to the region in which the stria of Gennari is present. Elliot Smith applies the name of "striated area" to this cortical district, and considers that it affords a means of identifying homologous sulci in the brains of man and the apes.

To obtain a full understanding of the minute structure of the cerebral cortex many different methods must be employed, and it is only by combining the several separate pictures which are thus afforded that the end in view is, in some measure, reached.

The stratification indicated above has little bearing upon the more essential points of the intimate structure of the cortex. The three white layers are brought about by aggregations of fibres running in a tangential direction, or, in other words, in a direction parallel to the surface of the convolution.

Nerve-cells.—According to the arrangement and the characters presented by the nerve-cells which are met with at different depths, it is now usual to recognise four layers in the cortex. These are: (1) the stratum zonale; (2) the layer of small pyramidal cells; (3) the layer of large pyramidal cells; and (4) the layer of polymorphic cells.

As the pyramidal cells are specially characteristic of the cerebral cortex, we shall, in the first instance, describe the two layers which contain them. The difference between these two layers largely depends upon the difference in the size of the constituent cells. Taken together, the second and third layers constitute the chief part of the cortex; they merge insensibly into each other, and, in the parietal and frontal lobes, the layer of large pyramidal cells is the thickest of all the layers. In both of these strata the pyramidal cells present the same form, and apparently also similar connexions.

A **pyramidal cell** has a triangular outline. Its apex is directed towards the surface of the convolution and is drawn out into a long, tapering, apical, dendritic process; its base is turned towards the medullary centre of the gyrus, and from this (usually from the centre) a slender axon proceeds. Numerous lateral dendrites are given off from both sides of the cell-body, and particularly from the two basal corners. The apical dendrite varies in length, according to the depth at which the cell is placed in the cortex. In every case it passes straight towards the surface of the convolution. Every here and there fine lateral branches come off from it, and ultimately it enters the stratum zonale, where, close to the surface, it ends by breaking up into a large number of fine terminal filaments, which spread out horizontally in every direction and interlace closely with the corresponding filaments of other pyramidal cells and with the other elements of this layer.

The axon of the cell descends, gives off collaterals, assumes a medullary sheath, and enters the central white core of the gyrus as a nerve fibre.

The **stratum zonale** is chiefly composed of fibres which run in a tangential direction, or, in other words, parallel to the surface. These form an interlacement of considerable density and extreme complexity. The elements which for the most part enter into the formation of this feltwork are: (1) the terminal filaments of the apical dendrites of the pyramidal cells; (2) the terminal filaments of certain corticipetal fibres, which enter the cortex from the white centre of the gyrus; (3) the axons of certain small cells peculiar to this stratum; (4) the axons of the cells of Martinotti. Spread over the surface of this tangential interlacement of fibres, which constitutes the most important part of the stratum zonale, there

is a thin layer of neuroglia which intervenes between it and the pia mater, which covers the convolution. The stratum zonale is not devoid of nerve-cells, although these are small and somewhat indefinite in their connexions. The most characteristic form is a small fusiform cell described by Cajal, which sends out from either end a long process and which lies in the deeper part of the layer. The long filamentous processes of this cell thread their way between the other fibres in a tangential direction and give off minute branches which pass towards the surface.

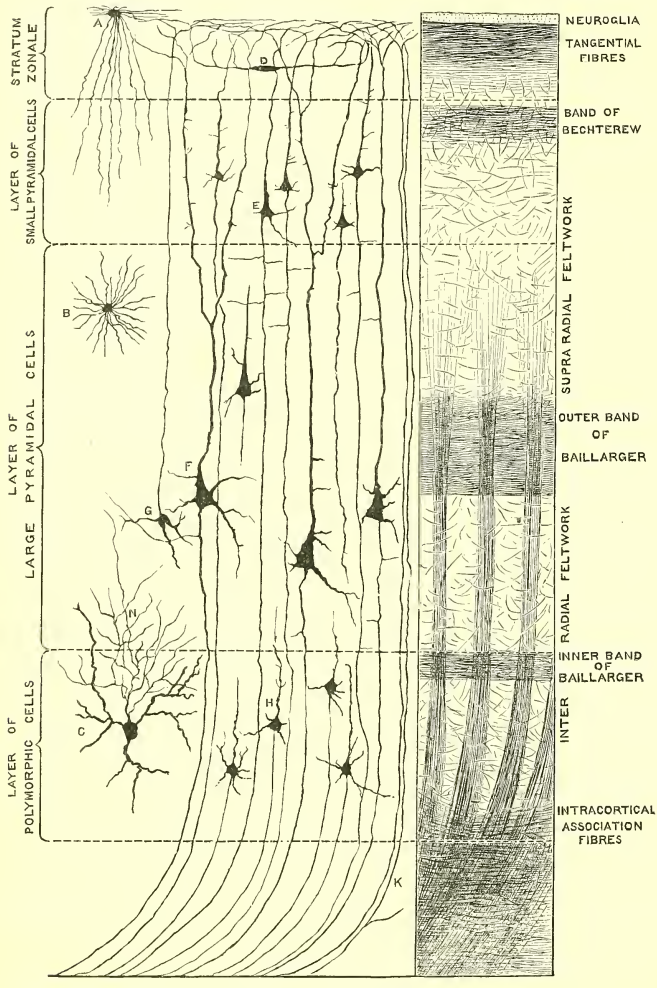


Fig. 469.—Diagram to Illustrate Minute Structure of the Cerebral Cortex.

A. } Neuroglia cells.
B. }
C. Cell with short axon (N) which breaks up in a free arborisation.
D. Spindle-shaped cell in stratum zonale.
E. Small pyramidal cell.
F. Large pyramidal cell.
G. Cell of Martinotti.
H. Polymorphic cell.
K. Corticipetal fibres.

The **deepest layer of the cortex** contains the polymorphic cells. These cells are not large, and they present many different forms. Numerous dendrites proceed from the cells of this group, but none of these reach the stratum zonale, and in this respect the polymorphic cells offer a marked contrast to the pyramidal cells. The axons of the polymorphic cells, however, like those of the pyramidal cells, enter the white centre of the gyrus in the shape of nerve-fibres.

In addition to the cells characteristic of the several layers, there are two which may be found amongst the pyramidal or amongst the polymorphic cells. These are: (1) the cells of Golgi; (2) the cells of Martinotti.

A **cell of Golgi** has this peculiarity—that its axon, close to its origin, begins to divide, and very soon loses its individuality by breaking up into a perfect maze of branches, none of which pass far from the neighbourhood of the cell-body and none of which enter the stratum zonale.

N Golgi

The **cell of Martinotti** is small and is chiefly found in the deeper part of the cortex. Its leading peculiarity is, that its slender axon runs in a contrary direction to the axons of the pyramidal cells and of the polymorphic cells. In other words, it proceeds towards the surface, and, entering into the stratum zonale, divides into terminal filaments, which spread out in the tangential interlacement characteristic of this layer.

Nerve-Fibres.—The arrangement of the nerve-fibres can best be studied in vertical sections through the gray cortex, which have been specially treated with this end in view. In such preparations bundles of nerve-fibres are seen to radiate into the gray cortex from the surface of the white centre of the gyrus. As these proceed through the polymorphic layer into the layer of large pyramidal cells, they gradually become less distinct, and, finally, they disperse and are lost to view before they reach the layer of small pyramidal cells. In the intervals between the radiating bundles the polymorphic and large pyramidal cells are arranged in columns, and in the same intervals an open

feltwork of intercrossing fibres is evident. After the radiating fibre-bundles have disappeared the same feltwork of fibres is visible in the gray matter, and consequently it is convenient to distinguish, with Edinger, an **inter-radial feltwork** and a **supra-radial feltwork** of fibres in the cortex. The fibres which enter into the composition of the different radial bundles vary in number from ten to twenty, and they gradually diminish in number as they proceed onwards. This diminution is due to their joining the various cells that they meet (both polymorphic and pyramidal) as their axons. The fibres in a given bundle also vary much in size, and it may be noticed that the largest fibres disappear in the vicinity of the large pyramidal cells, which shows clearly that it is with these that they are connected. But, in addition to cell-axons, the radial bundles contain fibres of an altogether different type, viz. corticipetal fibres, which pass through all the layers of the cortex and end in fine terminal filaments in the tangential interlacement of the stratum zonale.

The inter-radial and supra-radial feltwork is largely formed of the collaterals which issue from the axons. By a condensation of this feltwork the two bands of Baillarger are formed. The outer band, which is the broader and better marked, occurs in the deeper part of the layer of the large pyramidal cells. The inner band, when present, is formed in the superficial part of the layer of polymorphic cells.

Another condensation of the fibre-feltwork in the superficial part of the supra-radial region may be noted in certain localities. This is termed the **band of Bechterew.**

It has been noted that up to a certain point the tangential fibres increase in quantity as age advances, and there is reason to believe that upon the richness with which the gray cortex is supplied with fibres—more especially of the tangential variety—depends to some extent the intellectual capacity of an individual.

Whilst the general mass of the cortex for the most part conforms more or less closely to the ground-type described above, showing merely deviations characteristic of the different regions, there is one part of the cortex, viz. the cornu ammonis and the fascia dentata, in which the structural arrangement of the elements is very markedly different. To some extent this is due to the complicated manner in which, in this region, the cortex is folded upon itself.

Olfactory Tract and Bulb.

The olfactory tract and bulb arise as a hollow outgrowth from the primitive cerebral vesicle. In many animals with a well-developed olfactory apparatus, the tract and bulb remain hollow; but in man the central cavity becomes obliterated, although traces of the original hollow persist in the shape of ependymal remains, visible in the centre of both tract and bulb. Outside these ependymal elements is a coating of white matter, upon which is laid the gray matter. The gray matter, however, is by no means uniformly distributed over the surface. In the tract, except along the dorsal edge, it is so thinly spread that it is hardly appreciable. In the bulb, on the other hand, there is very little gray matter on the dorsum, but a considerable quantity on the ventral surface; and it is into this that the delicate nerves which enter the cranium through the cribriform plate of the ethmoid bone sink. A brief description of the structure of this infrabulbar mass of gray matter, as well as of the connexions established by its elements, now becomes necessary.

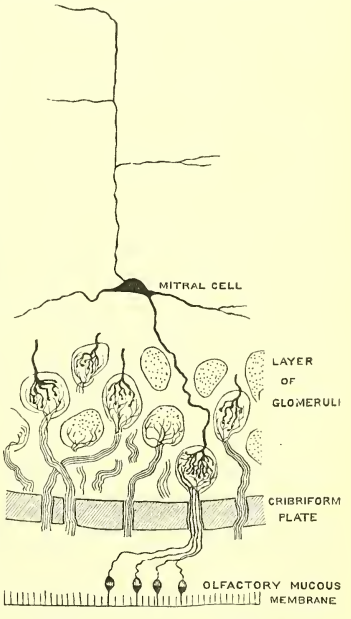


Fig. 470.—Diagram of the Minute Structure of the Olfactory Bulb.

The fibres of the delicate olfactory nerves are to be regarded as the axons of the olfactory cells of the olfactory mucous membrane. They enter the ventral surface of the olfactory bulb, and there each breaks up in an arborescent fashion into a tuft of terminal filaments. A thick dendrite from a mitral cell of the bulb passes down towards this terminal tuft, and, coming into contact with it, breaks up and terminates in a similar manner. In this way a large number of globular bodies, formed by the arborescent terminations of a mitral dendrite and of certain olfactory nerve-fibres, are formed. These are the **olfactory glomeruli** of the bulb. The mitral cells lie deeper in the olfactory bulb. Each gives

off several dendrites and one axon. Only one dendrite enters into the formation of a glomerulus, but several nerve-fibres may be connected with such a body. It thus happens that, through its dendrite, a mitral cell may stand in connexion with several olfactory nerve-fibres. The axon of the mitral cell passes upwards to the white matter of the bulb, enters this, and is conducted through the tract towards the cerebral cortex.

White Medullary Centre of the Cerebral Hemisphere.

The white matter of the hemisphere which lies subjacent to the gray cortex is composed of medullated nerve-fibres, arranged in a very intricate manner. According to the connexions which they establish these fibres may be classified into three distinct groups, viz. (1) commissural fibres; (2) association fibres; and (3) projection fibres.

Commissural Fibres.—These are fibres which link together portions of the gray cortex of opposite cerebral hemispheres. They are arranged in three groups forming three definite structures, viz. the corpus callosum, the anterior commissure, and the psalterium or the hippocampal commissure.

The **corpus callosum** has in a great measure been already studied (p. 570). As it enters each hemisphere, its fibres spread out in an extensive radiation (the radiation of the corpus callosum). It thus comes about that every part of the cerebral cortex, with the exception of the bulbus olfactorii and the under and fore part of the temporal lobe, is reached by the callosal fibres. But it should be clearly understood that all the regions of the cortex do not receive an equal proportion of fibres; in other words, some cortical areas would appear to be more plentifully supplied than others. Another point of some importance consists in the fact that the callosal fibres do not, as a rule, connect together symmetrical portions of the gray cortex. As the fibres cross the mesial plane they become greatly scattered, so that most dissimilar parts of the cortex of opposite hemispheres come to be associated with each other.

Each callosal fibre arises in one hemisphere and ends by fine terminal arborisations in the cortex of the opposite hemisphere. It may arise in any one of three ways, viz. (1) as the axon of one of the cortical cells, either pyramidal or polymorphic; (2) as the collateral of a fibre of association; (3) as the collateral of a fibre of projection.

Many cases have been recorded in which, through congenital defect, the corpus callosum has not been developed. In the description of this structure on p. 570 attention has been called to a layer of callosal fibres which sweep over the posterior and descending horns of the lateral ventricle, so as to form the immediate outer wall of the cavity. This layer is called the **tapetum**, and it has been stated that when the corpus callosum is absent the tapetum is found in a well-developed condition. Further, it has been asserted that in cases where the corpus callosum has been experimentally destroyed the tapetum suffered no degeneration (Muratoff). Certain anatomists are, therefore, inclined to argue that the tapetum has little or no connexion with the corpus callosum. This assertion, however, cannot by any means be regarded as being proved. There is a large amount of evidence on the other side. Thus, Mingazzini has seen a case of failure of the corpus callosum which was accompanied by a corresponding defect in the tapetum, whilst softening of the splenium and the forceps major has been observed by Anton to be accompanied by a secondary degeneration of the tapetum. Further, the recent experimental evidence of Ferrier and Turner would appear to support the older view that the tapetum is associated in the closest manner with the corpus callosum.

The **anterior commissure** (commissura anterior) is a structure supplemental to the corpus callosum. It connects together the two olfactory lobes, and also portions of opposite temporal lobes. It presents a cord-like appearance and is arranged in the form of a horse-shoe, the concavity of which looks backwards. The middle free portion is placed immediately in front of the anterior pillars of the fornix as they curve downwards, and also in intimate relation to the anterior end of the third ventricle. Posteriorly, the small portion of the anterior commissure which appears in the ventricle between the two pillars of the fornix is clothed with the ventricular ependyma; anteriorly, the commissure is connected with the lamina cinerea as it stretches from the optic chiasma upwards towards the rostrum of the corpus callosum.

The lateral part of the anterior commissure penetrates the cerebral hemisphere, and, gaining the lower part of the anterior end of the internal capsule, divides into two portions, viz. a small lower olfactory part and a much larger temporal part.

The **olfactory portion** of the anterior commissure is an exceedingly small fasciculus. It passes downwards and forwards, and finally enters the olfactory tract. It is composed (1) of true commissural fibres, which bind one olfactory bulb to the other; and (2) of other fibres, which connect the olfactory bulb of one side with the temporal lobe of the other side.

The **temporal portion** is formed of almost the whole of the fibres of the commissure. It is carried transversely outwards, under the lenticular nucleus, until it gains the interval between the globus pallidus and the putamen. At this point it

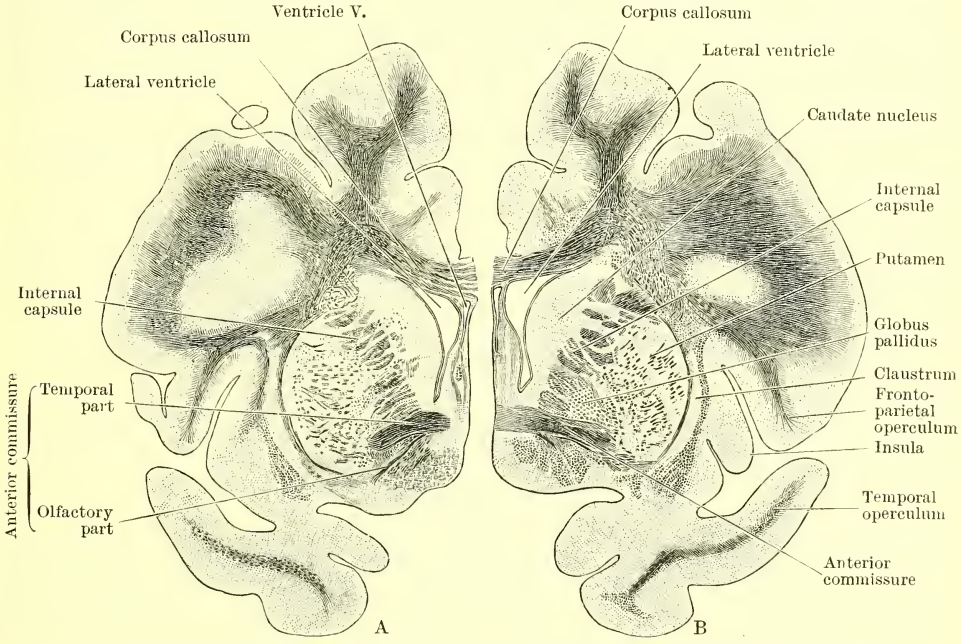


FIG. 471.—TWO CORONAL SECTIONS THROUGH THE CEREBRAL HEMISPHERES OF AN ORANG, IN THE PLANE OF THE ANTERIOR COMMISSURE.

A, Section through the left hemisphere in a plane a short distance behind B, which is a section through the right hemisphere.

changes its direction and sweeps backwards. In coronal sections through the brain, behind this bend, the temporal portion of the anterior commissure appears as an oval bundle of fibres cut transversely and placed in close contact with the under surface of the lenticular nucleus (Fig. 468, p. 582). Finally, it turns sharply downwards on the outer aspect of the amygdaloid nucleus, and its fibres are lost in the white medullary centre of the temporal lobe. The precise part of the cerebral cortex with which these fibres stand in connexion is not known. When the lateral part of the anterior commissure is displayed by dissection, it is seen to be twisted like a rope.

The **psalterium**, or the **hippocampal commissure**, is composed of fibres which connect the cornu ammonis of one side with the corresponding structure of the opposite side. It is described on p. 572.

Association Fibres.—The association fibres bind together different portions of the cortex of the same hemisphere. They are grouped into long and short association bundles.

The greater number of the **short association fibres** pass between adjacent convolutions. They curve round the bottom of the sulci in U-shaped loops. Some of these occupy the deepest part of the gray cortex itself, and are termed *intracortical association fibres* (Fig. 469, p. 586); others lie immediately subjacent to the gray matter—between it and the general mass of the white matter—and receive the name of *subcortical fibres*. Many groups of short association fibres, instead of linking together contiguous convolutions, pass between gyri more or less remote. It is only

after birth, when intellectual effort and education have stimulated different portions of the cortex to act in harmony and in conjunction with each other, that these association fibres assume their sheaths of medulla and become functional.

The **long association fibres** are arranged in bundles which run for considerable distances within the white medullary centre of the cerebral hemisphere, and unite districts of gray cortex which may be far removed from each other. The better known of these fasciculi are the following: (1) the uncinate; (2) the cingulum; (3) the superior longitudinal; (4) the inferior longitudinal; (5) the occipito-frontal.

The **fasciculus uncinatus** is composed of fibres which arch over the stem of the Sylvian fissure and connect the frontal pole, and the orbital convolutions of the frontal lobe, with the front portion of the temporal lobe.

The **cingulum** is a very well-marked and distinct band, which is closely associated with the limbic lobe. Beginning in front, in the region of the anterior perforated spot, it arches round the genu of the corpus callosum and is carried backwards on the upper surface of this structure at the place where its fibres pass into the

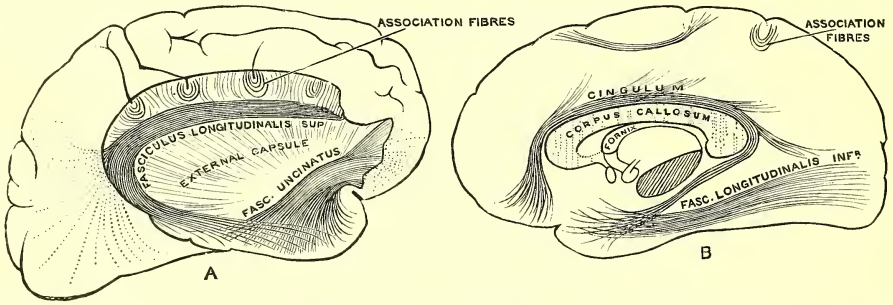


FIG. 472.—DIAGRAM OF THE LEADING ASSOCIATION BUNDLES OF THE CEREBRAL HEMISPHERE. (Founded on the drawings of Déjerine.)

A. Outer aspect of hemisphere. B. Inner aspect of hemisphere.

callosal radiation. The cingulum, therefore, lies under cover of the callosal gyrus and stands in intimate relation to the white centre of this convolution (Fig. 457, p. 570). At the hinder end of the corpus callosum the cingulum turns round the splenium and is carried forwards, in relation to the hippocampal gyrus, to the uncus and the temporal pole. The cingulum is composed of several systems of fibres which only run for short distances within it.

The **fasciculus longitudinalis superior** is an arcuate bundle which is placed on the outer aspect of the foot or basal part of the corona radiata and connects the frontal, occipital, and temporal regions of the hemisphere. It lies in the base of the fronto-parietal operculum and sweeps backwards over the insular region to the posterior end of the Sylvian fissure. Here it bends downwards round the hinder end of the putamen and proceeds forwards in the temporal lobe, to reach its anterior extremity. As it turns downwards to reach the temporal lobe numerous fibres radiate from it into the occipital lobe.

The **fasciculus longitudinalis inferior** is a very conspicuous bundle which extends along the whole length of the occipital and temporal lobes (Fig. 457, p. 570). In the occipital lobe it is placed on the outer aspect of the optic radiation, which takes a similar direction and from which it is distinguished by the greater coarseness of its fibres (Figs. 462, p. 576; 465, p. 578; 473, p. 592). It is not present in the macaque monkey (Ferrier and Turner), but is well developed in the orang and the chimpanzee,

The **fasciculus occipito-frontalis** is a bundle of fibres which runs in a sagittal direction in intimate relation to the lateral ventricle (Fig. 468, p. 582). It has been pointed out (Forel, Onufrowicz, and others) that, in cases where the corpus callosum fails to develop, the tapetum remains apparently unaffected, and Déjerine has endeavoured to prove that the fibres of this layer really belong to the fasciculus occipito-frontalis. According to Déjerine, the fasciculus occipito-frontalis lies on the inner aspect of the corona radiata in intimate relation to the caudate nucleus, and posteriorly it spreads out over the upper and outer aspect of the lateral ventricle, immediately outside the ependyma, where it constitutes the tapetum (see p. 588). There is a considerable amount of literature

dealing with this subject, and the most probable explanation of the difficulty would appear to be that the tapetum is composed of fibres derived from both the corpus callosum and the fasciculus occipito-frontalis of Déjerine.

Projection Fibres.—The projection fibres are those which connect the cerebral cortex with nuclear masses placed at a lower level. The great bulk of these fibres are found in the corona radiata. This has already been seen to be formed by the continuation upwards of the internal capsule (p. 583). In the corona radiata the fibres which, lower down, are gathered together in the compact mass which constitutes the internal capsule, radiate in every direction, intersect the radiation of the corpus callosum, and finally reach every region of the cortex. Although the fibres of the corona radiata represent the chief bulk of the projection fibres, it should also be borne in mind that a certain number gain the cortex by a different route, notably through and under the lenticular nucleus and by the path offered by the external capsule.

The projection fibres of the cerebral hemisphere may be classified into (1) corticipetal, and (2) corticifugal groups; and under these headings the following great strands may be arranged:—

Corticipetal Projection Strands.

1. Thalamo-cortical.
2. Corticipetal fibres of the optic radiation.
3. The auditory radiation.

Corticifugal Projection Strands.

1. The pyramidal or great motor tract.
2. The cortico-thalamic.
3. The fronto-pontine strand.
4. The temporo-pontine strand.
5. The corticifugal fibres of the optic radiation.

The **great motor** or **pyramidal tract** is composed of fibres which arise from pyramidal cells in that portion of the cortex which is spread over the Rolandic area, or, in other words, in the district immediately in front of the fissure of Rolando. The fibres descend through the corona radiata into the posterior limb of the internal capsule. From this point the further course of the pyramidal tract has been traced, viz. through the central part of the crusta of the crus cerebri, the ventral part of the pons, and the pyramid of the medulla oblongata. At the level of the foramen magnum it decussates in the manner already described, and enters the spinal cord as the crossed and direct pyramidal tracts. The fibres composing these end in connexion with the ventral or motor column of cells, from which the fibres of the anterior roots of the spinal nerves arise.

The **fronto-pontine strand** is composed of fibres which arise as the axons of the cells in the cortex which covers the portion of the frontal lobe, which lies in front of the præcentral furrows. It descends in the anterior limb of the internal capsule, enters the mesial part of the crusta of the crus cerebri, through which it gains the ventral part of the pons. In this its fibres end, by forming arborisations around the cells of the nucleus pontis.

The **temporo-pontine tract** consists of fibres which spring from the cells of that part of the cortex which covers the middle portions of the two upper temporal convolutions. It probably represents a corticifugal tract belonging to the auditory system, seeing that it springs to some extent from the auditory cortical area. The temporo-pontine tract passes inwards under the nucleus lenticularis, enters the retrolenticular part of the hinder limb of the internal capsule, and thus gains the outer part of the crusta of the crus cerebri. From this it descends into the ventral part of the pons, in which it ends in the nucleus pontis (Fig. 439, p. 546).

The **optic radiation** forms a very definite and easily demonstrated tract of longitudinally-directed fibres in the white medullary centre of the occipital lobe. It lies on the outer side of the ventricular cavity, from which it is separated by the fibres of the tapetum and the ependyma of the ventricle (Figs. 462, p. 576; and 465, p. 579). To the outer side of, and applied closely to, the optic radiation is another longitudinal tract of fibres in this part of the medullary centre of the cerebral hemisphere, viz. the inferior longitudinal association bundle; but the fibres of the latter fasciculus are coarser and are stained more deeply by the Pal-Weigert method, and thus they can, as a rule, be easily distinguished from the optic radiation. Traced

in a backward direction, the fibres of the optic radiation disperse and pass to the cortex of the occipital lobe on both its mesial and outer aspects. This is a matter of interest, seeing that the visual centre is placed in this cortical district, and more particularly on the mesial aspect in the immediate neighbourhood of the calcarine fissure (Flechsig and Henschen). When the optic radiation is followed in a forward direction it is seen to enter the retrolenticular part of the posterior limb of the internal capsule, from whence its fibres pass to the pulvinar of the optic thalamus, to the corpus geniculatum externum and the superior quadrigeminal body.

As we have noted, the optic radiation is composed partly of corticifugal and partly of corticipetal fibres (p. 552). The former arise from cells in the occipital cortex and end in the pulvinar and the superior quadrigeminal body; the corticipetal fibres arise in the pulvinar and in the corpus geniculatum externum and end in the occipital cortex (Ferrier and Turner).

The system of fibres which belong to the **mesial fillet** and the **superior cerebellar**

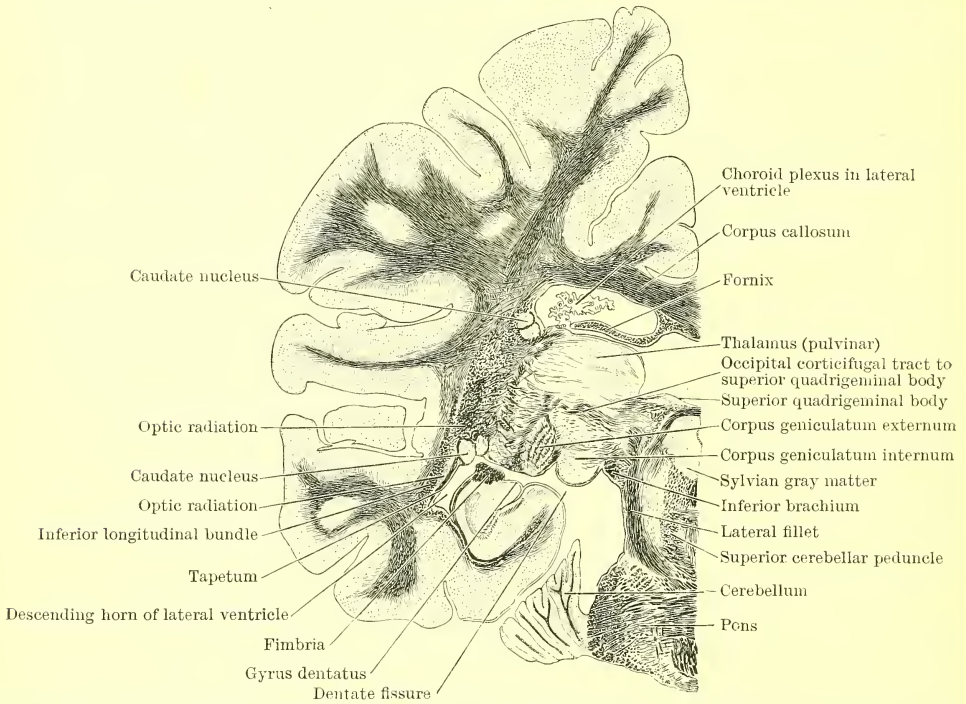


FIG. 473. — CORONAL SECTION THROUGH THE LEFT SIDE OF THE CEREBRUM, MESENCEPHALON, AND PONS, IN THE REGION OF THE PULVINAR OF THE THALAMUS, AND THE CORPORA GENICULATA (Chimpanzee; Weigert-Pal specimen).

peduncle have been already more or less fully dealt with (pp. 535 and 539). The **fillet system** represents the continuation upwards of the posterior columns of the cord. The first nuclear internodes in the system are met with in the medulla in the shape of the cuneate and gracile nuclei. It is here that the fillet first takes definite shape, and, as it passes upwards through the tegmental part of the medulla and pons, it receives many additions to its strength in the form of fibres from the nuclei of termination of the afferent cranial nerves. Finally, passing through the tegmentum of the mesencephalon, it reaches the subthalamic region and enters the ventral aspect of the thalamus. This may be looked upon as being the second internode laid across the path of the fillet, and its fibres end in arborisations around the thalamic cells.

The **fibres of the superior cerebellar peduncle** encounter two nuclear internodes as they pass towards the cerebral cortex, viz. the red tegmental nucleus and the optic thalamus (p. 536).

The **fibres of the auditory radiation** arise as the axons of cells situated in the internal geniculate body. They enter the retrolenticular part of the posterior limb of the internal capsule and proceed under the lenticular nucleus towards the

temporal lobe. Here they end in the area of cortex which constitutes the auditory centre. This corresponds to the middle portion of the superior temporal convolution, and also to the rudimentary transverse gyri of Heschl, which are present on the insular surface of the temporal operculum.

The **thalamo-cortical cortico-thalamic systems** include the fibres which constitute a double bond of connexion between the thalamus and all parts of the cortex. They are sufficiently described at p. 545.

The remarkable researches of Flechsig have added greatly to our knowledge of the different tracts of fibres in the cerebral hemisphere. By studying the periods at which these tracts myelinate he has been able to note the manner in which the different areas of the cortex are bound together and also linked on to subjacent centres. He has arrived at a highly important conception regarding the functional value of different districts of the cortex, founded upon their anatomical connexions. He recognises four sense-areas in the cortex, viz. the somæsthetic area, the visual area, the auditory area, and the olfactory area.

The **somæsthetic area** is the field of general sensibility and is the most extensive of all. It includes the two central convolutions, the posterior portions of the three frontal convolutions, the paracentral convolution, and the adjoining part of the callosal convolution.

The **visual area** is placed on the inner aspect of the occipital lobe, and more particularly in the immediate neighbourhood of the calcarine fissure.

The **auditory area** corresponds to the middle third of the superior temporal convolution and to the transverse gyri of Heschl.

The **olfactory area** includes the locus perforatus anticus, the trigonum olfactorium, the anterior part of the callosal convolution, and the uncus.

These sense-areas are peculiarly rich in their supply of projection fibres, and each is provided with an extensive system of both corticifugal and corticipetal fibres. Thus the somæsthetic area

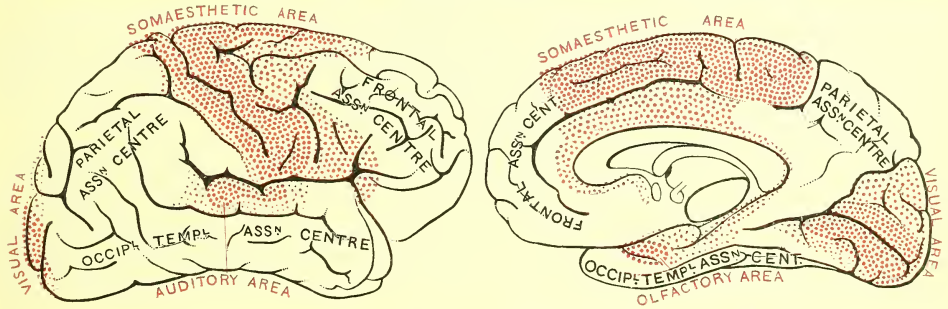


Fig. 474.—Diagrams to show Flechsig's sensory and association areas on the surface of the cerebral hemisphere.

is the field where the motor pyramidal tract takes origin and within which the tracts of general sensibility end. The visual area has the corticipetal and corticifugal fibres of the optic radiation. The auditory area has the corticipetal auditory radiation and also the corticifugal temporo-pontine tract. In man the olfactory area is feebly developed, and Flechsig has not been able to establish, with certainty, its corticipetal and corticifugal projection tracts.

The sense-areas differ greatly from each other in the extent of cerebral surface which they cover. The size in each case is in strict conformity with the peripheral area with which each is in connexion. It can easily be understood, therefore, how the somæsthetic area, representing as it does on the cortex all the parts of the body outside the special organs of sense, from which sensory nerves proceed, should be so large. Further, it is manifest why the visual sensorial area, which in the cortex is the corresponding part to the retina, should be of greater extent than the auditory field, which represents the cochlea, and the olfactory area, which represents a small amount of olfactory mucous membrane in the nasal chamber.

The four sensorial areas, taken together, only form about one-third of the entire cerebral surface. The remaining two-thirds of the cortex constitute what Flechsig has termed the **association centres**. The great extent of these in man must be regarded as a special human characteristic. These centres differ from the sensorial areas in being poorly provided with projection fibres. They have little direct connexion with the centres which lie at a lower level. Indeed, the only direct bond of union over a very large extent of these association areas with lower centres consists of the thalamo-cortical fibres, which pass to them from the thalamus. But, on the other hand, they are rich in association fibres, and are linked in the most complete and perfect manner by these fibres to the sensorial areas.

Flechsig regards these association areas as constituting the portions of cortex in which the higher intellectual activities are carried on, and he further believes that they exercise an important controlling influence over the sense-areas. More particularly is this control exhibited in the case of the great somæsthetic area, within which the influence of all bodily impressions is received and transformed into consciousness, and within which the impulses which are thereby

excited take definite form. These impulses, according to Flechsig, are, in a measure, in all properly-balanced minds, held in subjection by the higher feelings, which assume shape in the association centres.

In his study of the fœtal and infantile brain Flechsig has shown that the fibres of the sensory paths become medullated in the first instance; then the corticifugal fibres which go out from the sense-areas assume their sheaths of myelin; and, further, that it is not until a month after birth, and after the projection fibres in connexion with the sense-areas are myelinated, that the association areas become linked on by medullated association fibres with the sense-areas.

Development of the Parts derived from the Fore-brain.

It has been previously noted that the fore-brain very early shows an obscure subdivision into a front portion, termed the telencephalon, and a hinder part, called the diencephalon, which corresponds more nearly to the original cavity of the fore-brain. The cavity of third ventricle is derived from both, and stretches forwards, therefore, to the lamina terminalis, which in its lower part is represented in the adult by the lamina cinerea.

The lateral wall of both sections of the primitive fore-brain shows a subdivision into a dorsal or alar and a ventral or basal lamina. The groove which indicates this separation is the sulcus of Monro, and is evident even in the adult brain.

In recognising an alar and basal lamina in the fore-brain the teaching of Professor His is followed. This subdivision, however, is not admitted by all observers, and some hold that the fore-brain is to be regarded as a great diverticular expansion which grows out from the mid-dorsal and alar laminæ of the mesencephalon.

Alar Lamina.—The alar part of the lateral wall of the *telencephalon* is pushed out to form the diverticulum, which ultimately constitutes the cerebral hemisphere, and thus from a very early period the primitive position of this part of the lateral wall is indicated by the wide foramen of Monro, or aperture of communication between the cavity of the cerebral hemisphere and the third ventricle.

The alar part of the lateral wall of the *diencephalon* is utilised for the development of the thalamus, the epithalamus, and the metathalamus. Of these the optic thalamus is derived from the anterior and by far the greatest part of the alar wall. It arises as a large oval swelling, which gradually approaches its fellow of the opposite side, and thus diminishes the width of the third ventricle. Finally, the two bodies come into contact in the mesial plane and cohere over an area corresponding to the gray commissure. This occurs about the end of the second month.

From that section of the lateral wall to which the name of metathalamus is given the two geniculate bodies arise. Each of these shows, in the first place, as a depression on the inside, and a slight elevation on the outside, of the wall of the diencephalon. As the thalamus grows backwards, it encroaches greatly upon the territory occupied by the geniculate bodies. It thus comes about that in the adult brain the internal geniculate body seems to hold a position on the lateral aspect of the mesencephalon, whilst the external geniculate body, viewed from the surface, appears to be a part of the thalamus.

From the epithalamic region of the wall of the diencephalon are developed the pineal gland, its peduncle, and the habenular region. These parts are relatively much more evident in the embryonic than in the adult brain. The pineal body is developed as a diverticulum of the posterior part of the roof of the diencephalon. Viewed from the dorsal aspect of the brain-tube, this diverticulum shows in the first instance as a rounded elevation, from either side of which a broad ridge runs forwards. This ridge becomes the tænia thalami, whilst in the region of its junction with the pineal elevation the trigonum habenulæ takes shape. The pineal diverticulum ultimately becomes solid, but a small portion of the original cavity is retained as the recessus pinealis of the third ventricle.

Basal Lamina.—The part of the diencephalon and telencephalon which represents the basal lamina lies below the level of the sulcus of Monro, retains its primitive form, and undergoes only slight change. Consequently, when this region in the adult brain is compared with the corresponding region in the embryonic brain, the resemblance between the two is very striking.

In the fore-brain, therefore, it is the alar lamina which plays the predominant part in the formation of the cerebrum. The value, also, of the basal part of the wall of this portion of the neural tube is still further reduced by the fact that it no longer contains the nuclei of origin of efferent nerves. The highest of these nuclei (the oculo-motor) is placed in the mesencephalon.

The region of the fore-brain which lies below the sulcus of Monro is termed the hypothalamus. The part of this which corresponds to the diencephalon is called the pars mammillaris hypothalami, whilst the part in front, which belongs to the telencephalon, receives the name of pars optica hypothalami.

From the pars mammillaris hypothalami are derived the corpus mammillare and a portion of the tuber cinereum. With the pars optica hypothalami are associated the following parts, viz. the tuber cinereum, with the infundibulum and the cerebral part of the pituitary body, the optic chiasma, the optic recess, and the lamina cinerea.

The corpora mammillaria form, in the first instance, a relatively large downward bulging of the floor of the brain-tube. As development goes on this bulging becomes relatively small, and about the fourth month the single projection becomes divided into the two tubercles.

The infundibulum and posterior or cerebral lobe of the pituitary body are developed as a hollow downward diverticulum of the floor of the telencephalon (p. 549). A portion of the original cavity is retained in the upper part of the infundibulum, and constitutes the infundibular recess in the floor of the third ventricle.

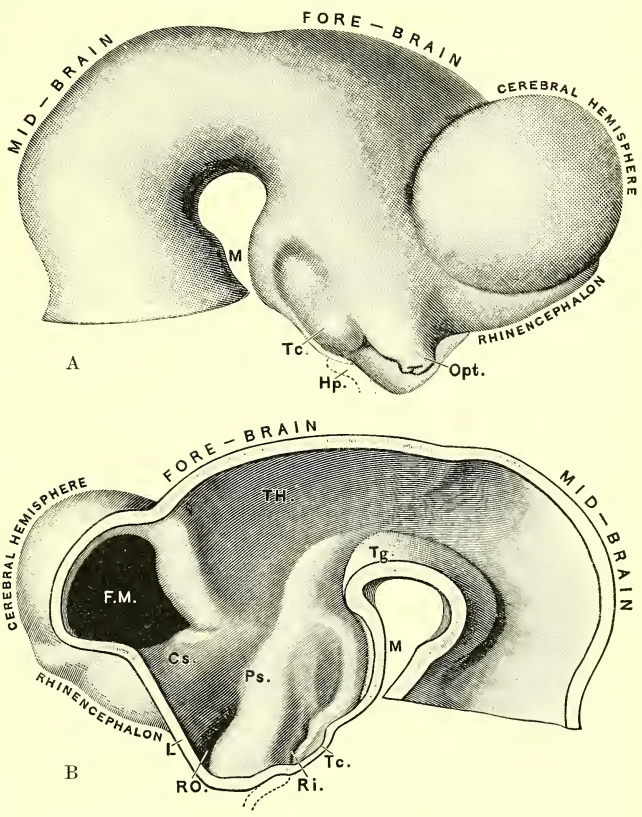


Fig. 475.—Two Drawings of the Embryonic Brain (by His).

A, Reconstruction of the fore-brain and mid-brain of His's embryo KO; profile view. B, Same brain as A, divided along the mesial plane and viewed upon its inner aspect.

M, Mammillary eminence; T.c, Tuber cinereum; Hp, Hypophysis (pituitary diverticulum from buccal cavity); Opt, Optic stalk; TH, Optic thalamus; Tg, Tegmental part of mesencephalon; P.s, Par subthalamica; C.s, Corpus striatum; F.M, Foramen of Monro; L, Lamina terminalis; R.O, Recessus opticus; R.i, Recessus infundibuli.

The optic nerve is chiefly formed by the passage of fibres backwards from the retina in the wall of the original optic stalk, whilst the chiasma takes form by the transit of fibres across the middle line in front of the infundibulum and behind the optic recess. To a large extent these fibres are derived from the optic nerve. The optic recess of the third ventricle marks the spot where the hollow optic vesicle originally bulged out from the lower and lateral part of the fore-brain, and in the adult it therefore represents a portion of the primitive cavity of the tubular stalk of the optic vesicle. In the course of development the optic nerve fibres, which appear in the stalk of the optic vesicle to form the optic nerve, seek an attachment much further back, and through the optic tract they are even carried as far as the mesencephalon.

The **roof of the fore-brain** remains thin, and does not proceed to the development of nervous elements, except in its posterior part. Here it forms the pineal body and the posterior commissure. In front of these structures the roof of the fore-brain is epithelial, and remains so during life. It constitutes the epithelial roof of the third ventricle, and it becomes involuted along the middle line into the cavity by the choroid plexuses of the ventricle. The posterior commissure appears as a transverse thickening at the bottom of a transverse groove which appears in the roof of the early brain-tube behind the pineal diverticulum.

Cerebral Hemisphere.—The cerebral hemisphere is derived from the alar section of the lateral wall of the telencephalon. From this it grows out and soon assumes very large dimensions. At first it grows forwards and upwards, and a distinct fissure, the

early incisura longitudinalis cerebri, appears between the cerebral hemispheres of opposite sides. The separation of the two cerebral vesicles by the longitudinal fissure begins at the end of the first month. This fissure becomes occupied by mesoblastic tissue, which later on forms the falx cerebri. The cerebral hemisphere, in its further growth, is carried progressively backwards over the hinder parts of the developing brain. At the end of the third month it has covered the optic thalamus. A month later it reaches the corpora quadrigemina, and by the seventh month it has not only covered these, but also the entire upper surface of the cerebellum.

At the end of the first month the olfactory lobe grows out as a hollow protrusion from

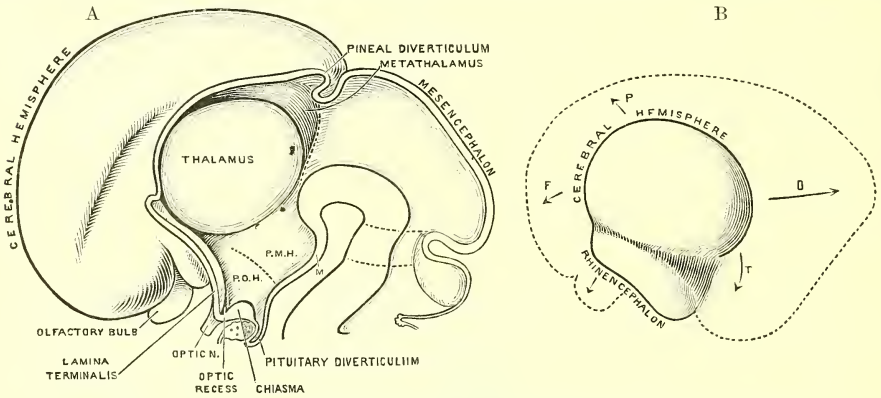


Fig. 476.—Two Drawings by His, illustrating the development of the human brain.

A, Median section through a fœtal human brain in the third month of development.
B, Schema showing the directions in which the cerebral hemisphere expands during its growth.

P.M.H. Pars mammillaris hypothalami.
P.O.H. Pars optica hypothalami.
M. Mammillary region.
F. Frontal lobe.
P. Parietal lobe.
O. Occipital lobe.
T. Temporal lobe.

the lower and fore part of the cerebral vesicle. This in course of time becomes solid and forms the olfactory tract and bulb. In the adult brain the point which corresponds to the original connexion between the early hollow olfactory diverticulum and the cavity of the cerebral vesicle is represented by the extremity of the anterior cornu of the lateral ventricle.

In the floor of the hollow cerebral hemisphere a thickening takes origin, and this ultimately is developed into the corpus striatum. On the outer surface of the vesicle this thickening is seen to correspond to a depression which constitutes the early Sylvian fossa, the further development of which is described on p. 556.

In the earlier stages of its development the cerebral hemisphere is a thin-walled vesicle with a relatively large cavity, which represents the primitive condition of the lateral ventricle. At first the vesicle is bean-shaped and the cavity is curved. At this stage the outline is very similar to that presented by the cerebral hemisphere of a quadruped, and there is little or no trace of an occipital lobe or of a posterior horn of the lateral ventricle. As development goes on, however, the occipital portion of the hemisphere grows backwards over the cerebellum in the shape of a hollow protrusion, and a distinct occipital lobe enclosing the posterior horn of the lateral ventricle is the result. This developmental stage, which is distinctive of man and the apes, begins about the fourth month.

On the mesial aspect of the cerebral hemisphere, in the early stages of its development, an invagination of the wall of the vesicle takes place into the cavity immediately above and behind the large foramen of Monro. This is the choroidal fissure, and the fold of the cerebral wall, which is thus thrust into the cavity, remains thin and entirely epithelial. After a time mesoblastic tissue from the great longitudinal fissure finds its way into the choroidal fissure and occupies the interval between the two thin layers which form the fold. This mesoblastic tissue forms the choroid plexus of the lateral ventricle, and in the early stages of the hemisphere it is so voluminous that it fills up the relatively large cavity of the lateral ventricle.

Development of the Gyri and Sulci.—In the early stages of its development, the surface of the cerebral hemisphere is smooth and closely applied to the deep surface of the cranial capsule within which it is enclosed.

After the occipital lobe is fully formed and the fifth month is reached, the cranium grows for a time more rapidly than the brain, with the result that a relatively wide space is

left between the cerebral surface and the surrounding cranial envelope. This is occupied by sodden subarachnoid tissue, and when this stage is reached (in the latter part of the fifth month) the sulci and gyri begin to make their appearance. The incomplete sulci owe their origin to the upheaval of the cerebral cortex on either side of the appearing fissures, and the gyri which bound them are formed as the result of an exuberance of surface growth in localised areas. Owing to the wide interval between the cranial wall and the surface of the cerebral hemisphere, the particular surface areas which grow and foreshadow the future gyri suffer no restriction, and they take the form of rounded eminences which rise from the general surface level of the cerebral hemisphere. As growth goes on, however, the brain gradually assumes a bulk more nearly in accord with the cavity of the cranium, and the space for extension becomes more limited. Finally, about the beginning of the eighth month, the gyral elevations come into close contact with the cranial wall, and a stage of growth-antagonism between the brain and its enclosing capsule is entered upon. As a result of this the gyri are pressed together, the fissures assume more definite shape, and the ordinary convolutionary forms make their appearance. So intimate, indeed, is the contact between the cerebral hemisphere and the skull capsule that the gyri, to some extent, produce an imprint on the deep aspect of the cranial bones.

As already explained, the complete fissures are produced by an infolding of the wall of the cerebral vesicle.

Cerebral Commissures.—The development of the cerebral commissures is surrounded with much difficulty. It would seem that the corpus callosum, the anterior commissure, and the fornix all take origin in the lamina terminalis. The triangular interval which is left between these commissures is occupied by the septum lucidum—a structure which has an intimate developmental and morphological connexion with the gyrus subcallosus. The great development of the corpus callosum in man is to be associated with the enormous expansion of the human neo-pallium of which it is the commissure.

Weight of the Brain.

The average weight of the adult male brain may be said to be about 1360 grammes. The female brain weighs rather less, but this is to be expected from the smaller bulk of the female body. Probably the relative weight of the brain in the two sexes is very much the same. The variations met with in brain-weight are very great, but it is doubtful if normal intellectual functions could be carried on in a brain which weighs less than 960 grammes. In microcephalic idiots brains of extremely small size are met with.

THE MENINGES OF THE BRAIN AND SPINAL CORD.

The brain and spinal cord are enclosed within three membranes, which are termed the meninges or meningeal membranes. From without inwards these are: (1) the dura mater, (2) the arachnoid mater, and (3) the pia mater. The space between the dura mater and the arachnoid receives the name of subdural space, while the much more roomy interval between the arachnoid and the pia mater is called the subarchnoid space.

Dura Mater.

The dura mater is a dense and thick fibrous membrane which possesses a very considerable degree of strength. Its arrangement within the cranial cavity is so different from that within the spinal canal that it is customary to speak of it as consisting of two parts, viz. a cranial and a spinal, although in adopting this subdivision it must be clearly understood that both portions are continuous with each other at the foramen magnum.

Cranial Dura Mater (dura mater cerebri).—The cranial dura mater is adherent to the inner surface of the cranial wall, and performs a double office. It serves as an internal periosteum for the bones which it lines and constitutes an envelope for the brain. Its inner surface, which bounds the subdural space, is smooth and glistening, and is covered by a layer of endothelial cells. The outer surface, when separated from the cranial wall, is rough, this being due to numerous fine fibrous processes and blood-vessels which pass between it and the bones. Its degree of

adhesion to the cranial wall differs considerably in different regions. To the vault of the cranium, except along the lines of the sutures, the connexion is by no means strong, and in the intervals between the fibrous processes which pass into the bone there are small lymph spaces (epidural spaces) where the outer surface of the membrane is covered by endothelial cells. So long as the sutures are open the dura mater is connected with the periosteum on the exterior of the skull, along the sutural lines, by a thin layer of fibrous tissue which intervenes between the bony margins. Around the foramen magnum, and to the floor of the cranium, the dura mater is very firmly adherent. This is more particularly marked in the case of the projecting parts of the cranial floor, as, for example, the petrous portions of the temporal bones, the clinoid processes, and so on. This firm adhesion in these regions is still further strengthened by the fact that the nerves, as they leave the cranium through the various foramina, are followed by sheaths of the fibrous dura

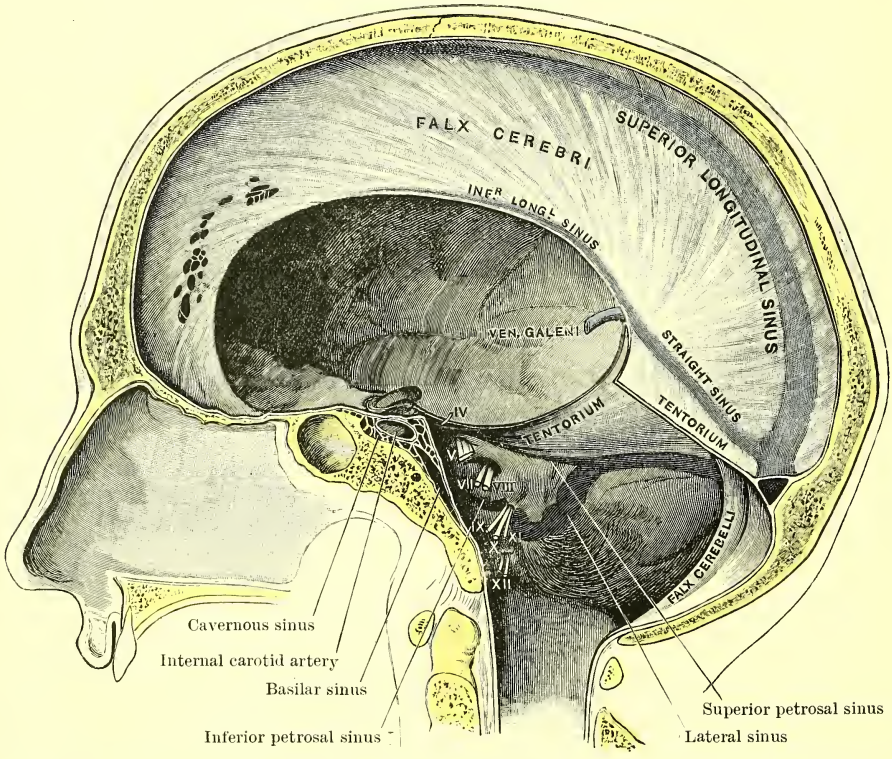


FIG. 477.—SAGITTAL SECTION THROUGH THE SKULL, A LITTLE TO THE LEFT OF THE MESIAL PLANE, to show the arrangement of the dura mater.

The cranial nerves are indicated by numerals.

mater. Outside the cranium these prolongations of the membrane blend with the fibrous sheaths of the nerves, and likewise become connected with the periosteum on the exterior of the skull. In the child, during the growth of the cranial bones, and also in old age, the dura mater is more adherent to the cranial wall than during the intermediate portion of life.

The cranial dura mater is composed of two layers intimately connected with each other, but yet capable of being demonstrated in most regions of the cranium. Along certain lines these two layers separate from each other so as to form channels lined by endothelium. These channels are the **venous blood-sinuses** which receive the blood from veins which come from various parts of the brain. They are described in the section dealing with the Vascular System.

Strong fibrous partitions or septa are given off along certain lines from the deep surface of the dura mater. These project into the cranial cavity, and subdivide it partially into compartments which all freely communicate with each other, and

each of which contains a definite subdivision of the brain. These septa are: (1) the falx cerebri; (2) the tentorium cerebelli; (3) the falx cerebelli; and (4) the diaphragma sellæ.

The **falx cerebri** is a sickle-shaped partition which descends in the great longitudinal fissure between the two hemispheres of the cerebrum. In front it is narrow, and attached to the crista galli of the ethmoid bone. As it is followed backwards it increases in breadth, and behind it is attached along the mesial plane to the upper surface of the tentorium. The anterior narrow part of the falx is frequently cribriform, and is sometimes perforated by apertures to such an extent that it almost resembles lace-work. Along each border it splits into two layers, so as to enclose a blood-sinus. Along its upper convex attached border runs the *great longitudinal sinus*; along its concave free border courses the much smaller *inferior longitudinal sinus*; whilst along its attachment to the tentorium is enclosed the *straight sinus*.

The **tentorium cerebelli** is a large crescentic partition of dura mater, which forms a membranous tent-like roof for the posterior cranial fossa, and thus intervenes between the posterior portions of the cerebral hemispheres and the cerebellum. It is accurately applied to the upper surface of the cerebellum. Thus its highest point is in front and in the mesial plane, and from this it slopes downwards towards its attached border. It is kept at a high degree of tension, and this depends on the integrity of the falx cerebri, which is attached to its upper aspect in the mesial plane.

The *posterior border* of the tentorium is convex, and is attached to the horizontal ridge which marks the deep surface of the occipital bone. Beyond this, on each side, it is fixed to the postero-inferior angle of the parietal bone, and then forwards along the superior border of the petrous portion of the temporal bone. From the internal occipital protuberance to the postero-inferior angle of the parietal bone this border encloses the *lateral blood-sinus*, whilst along the upper border of the petrous bone it encloses the *superior petrosal sinus*. The *anterior border* of the tentorium is sharp, free, and concave, and forms with the dorsum sellæ an oval opening shaped posteriorly like a pointed arch. This opening receives the name of the **incisura tentorii**, and within it is placed the mesencephalon, or the stalk of connexion between the parts which lie in the posterior cranial fossa and the cerebrum. Beyond the apex of the petrous part of the temporal bone the two margins of the tentorium cross each other like the limbs of the letter X; the free margin is continued forwards, to be attached to the anterior clinoid process, whilst the attached border proceeds inwards, to be fixed to the posterior clinoid process.

The **falx cerebelli** is a small, sickle-shaped process of dura mater placed below the tentorium, which projects forwards in the mesial plane from the internal occipital crest. It occupies the notch which separates the two hemispheres of the cerebellum posteriorly. Inferiorly it bifurcates into two small diverging ridges which gradually fade away as they are traced forwards on either side of the foramen magnum.

The **diaphragma sellæ** is a small circular fold of dura mater which forms a roof for the pituitary fossa. A small opening is left in its centre for the transmission of the infundibulum.

Spinal Dura Mater (dura mater spinalis).—In the spinal canal the dura mater forms a tube which encloses the spinal cord, and which extends from the foramen magnum above to the level of the second or third piece of the sacrum below. It is very loosely applied to the spinal cord and the nerve-roots which form the cauda equina; in other words, it is very capacious in comparison with the volume of its contents. Moreover, its calibre is not uniform. In the cervical and lumbar regions it is considerably wider than in the dorsal region, whilst in the sacral canal it rapidly contracts, and finally ends by blending with the filum terminale externum, the chief bulk of which it forms. At the upper end of the spinal canal the spinal dura mater is firmly fixed to the third cervical vertebra, to the axis vertebra, and around the margin of the foramen magnum. In the sacral canal the filum terminale externum, with which it blends, extends downwards to the back of the coccyx, to the periosteum of which it is fixed. The lower end of the tube is thus securely anchored and held in its place.

Within the cranial cavity the dura mater is closely adherent to the bones, and forms for them an internal periosteum. As it is followed into the spinal canal its two constituent layers separate. The inner layer is carried downwards as the long cylindrical tube which encloses the spinal cord. The outer layer, which is much thinner, becomes continuous behind and on each side of the foramen magnum with the periosteum on the exterior of the cranium, whilst in front it is prolonged downwards into the vertebral canal in connexion with the periosteum and ligaments on the anterior wall of the canal. The spinal dura mater, therefore, corresponds to the inner layer of the cranial dura mater, and to it alone. It is separated from the walls of the spinal canal by an interval, the **epidural space**, which is occupied by soft fat and a plexus of thin-walled veins. In connexion with the spinal dura mater there are no blood-sinuses such as are present in the cranial cavity, but it should be noted that the veins in the epidural space, placed as they are between the periosteum of the spinal canal and tube of dura mater, occupy the same morphological plane as the cranial blood-sinuses. Another feature which serves to distinguish the spinal dura mater from the cranial dura mater consists in the fact that it gives off from its deep surface no partitions or septa.

The cylindrical tube of spinal dura mater does not lie absolutely free within the vertebral canal. Its attachments, however, are of such a character that they in no way interfere with the free movement of the vertebral column. On either side the spinal nerve-roots, as they pierce the dura mater, carry with them into the intervertebral foramina tubular sheaths of the membrane, whilst in front loose fibrous prolongations—more numerous above and below than in the dorsal region—connect the tube of dura mater to the posterior common ligament of the vertebral column. No connexion of any kind exists between the dura mater and the posterior wall of the spinal canal.

When the interior of the tube of spinal dura mater is inspected, the series of apertures of exit for the roots of the spinal nerves is seen. These are ranged in pairs opposite each intervertebral foramen.

Viewed from the inside of the tube of dura mater, each of the two roots of a spinal nerve is seen to carry with it a special and distinct sheath. When examined on the outside, however, the appearance is such that one might be led to conclude that both roots are enveloped in one sheath of dura mater. This is due to the fact that the two sheaths are firmly held together by intervening connective tissue. The two tubular sheaths remain distinct as far as the ganglion on the posterior root, and then blend with each other.

Subdural Space.—The dura mater and the arachnoid mater are closely applied to each other, and the capillary interval between them is termed the subdural space. It contains a minute quantity of fluid, which is just sufficient in amount to moisten the opposed surfaces of the two bounding membranes.

The subdural space in no way communicates with the subarachnoid space. The fluid which it contains is led into the venous blood-sinuses around the Pacchionian bodies, and thus gains exit. The subdural space is carried outwards for a very short distance on the various nerves which are connected with the brain and the spinal cord, and it has a free communication with the lymph-paths present in these nerves. In the case of the optic nerve the sheath of dura mater is carried along its whole length, and with it the subdural space is likewise prolonged to the back of the eyeball.

The Arachnoidea.

The arachnoid mater is a very thin membrane, remarkable for its delicacy and transparency, which envelopes both the brain and the cord between the dura mater and the pia mater. The cranial part of the arachnoid mater or the **arachnoidea encephali**, except in the case of the great longitudinal and the Sylvian fissures, does not dip into the sulci on the surface of the brain. In this respect it differs from the pia mater. It bridges over the inequalities on the surface of the brain. Consequently, on the basal aspect of the encephalon it is spread out in the form of a very distinct sheet over the medulla, the pons Varolii, and the hollow which lies

in front of the pons, and in certain of these regions it is separated from the brain-surface by wide intervals.

The spinal part of the arachnoid mater or **arachnoidea spinalis**, which is directly continuous with the cranial arachnoidea, forms a loose wide investment for the spinal cord. This arachnoidal sac is most capacious towards its lower part, where it envelopes the lower end of the cord and the collection of long nerve-roots which constitute the cauda equina.

As the nerves, both from the brain and the cord, pass outwards they receive an investment from the arachnoid, which runs for a short distance upon them and then comes to an end.

Subarachnoid Space (cavum subarachnoidale).—The interval between the arachnoidea and the pia mater receives the name of the subarachnoid space. It

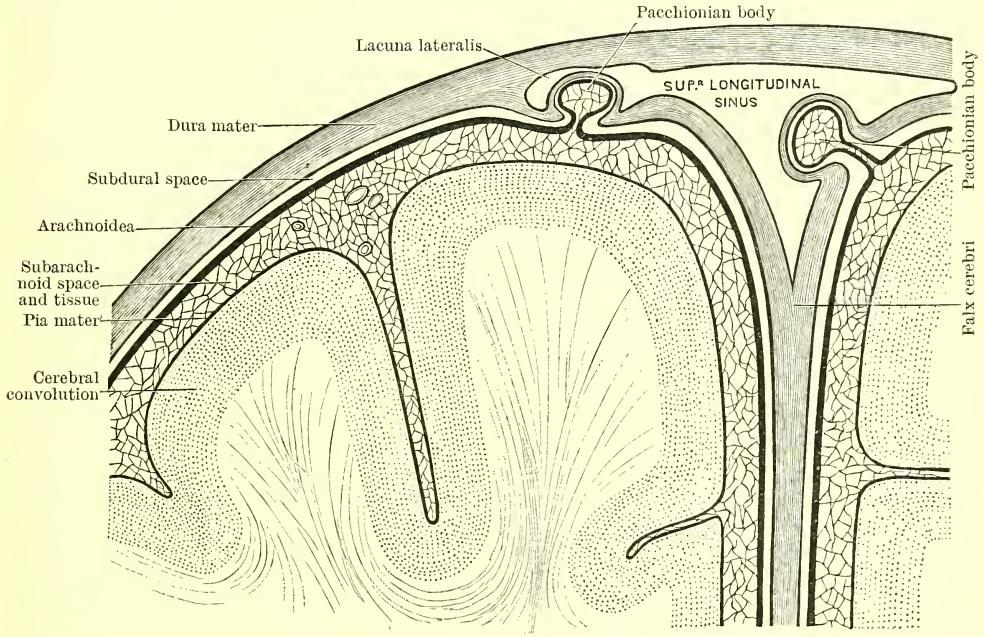


FIG. 478.—DIAGRAM to show the relations of the membranes of the brain to the cranial wall and the cerebral convolutions, and also of the Pacchionian bodies to the superior longitudinal sinus and the lateral lacunæ.

contains the cerebro-spinal fluid, and communicates freely through certain well-defined apertures with the ventricular cavities in the interior of the brain. Three of these (viz. the foramen of Majendie and another at the extremity of each lateral recess) are in connexion with the fourth ventricle; two are slit-like openings into the lateral ventricles, and are placed at the extremity of each descending horn.

Within the cranium the subarachnoid space is broken up by a meshwork of fine filaments and trabeculæ, which connects the two bounding membranes (viz. the arachnoidea and the pia mater) in the most intimate manner, and forms a delicate sponge-like interlacement between them. Where the arachnoidea passes over the summit of a cerebral convolution, and is consequently closely applied to the subjacent pia mater, the meshwork is so dense and the trabeculæ so short that it is hardly possible to discriminate between the two membranes. To all intents and purposes they form in these localities one lamina. In the intervals between the rounded margins of adjoining convolutions, however, distinct angular spaces exist, where the subarachnoid trabecular tissue can be studied to great advantage. These intervals on the surface of the cerebrum constitute numerous communicating channels which serve for the free passage of the subarachnoid fluid from one part of the brain to another. The larger branches of the arteries and veins of the brain traverse the subarachnoid space; their walls are directly connected with the subarachnoid trabeculæ, and are bathed by subarachnoid fluid.

In certain situations within the cranium the arachnoidea is separated from the

pia mater by intervals of considerable width and extent. These expanded portions of the subarachnoid space are termed **cisternæ subarachnoidales**. In these the subarachnoid tissue is much reduced. There is no longer a close meshwork; the trabeculæ connecting the two bounding membranes take the form of long filamentous intersecting threads which traverse the spaces. All the subarachnoid cisterns communicate in the freest manner with each other and also with the narrow channels on the surface of the cerebrum.

Certain of these cisterns require special mention. The largest and most conspicuous is the **cisterna magna**. It is formed by the arachnoid membrane bridging over the wide interval between the back part of the under surface of the cerebellum and the medulla. It is continuous through the foramen magnum with the posterior part of the wide subarachnoid space of the cord.

The **cisterna pontis** is the continuation upwards on the floor of the cranium of the anterior part of the subarachnoid space of the spinal cord. In the region of the medulla it is continuous behind with the cisterna magna, so that this subdivision of the brain, like the spinal cord, is surrounded by a wide subarachnoid space.

In front of the pons Varolii the arachnoidea bridges across between the projecting temporal lobes, and covers in the deep hollow in this region of the brain. This space is called the **cisterna basalis**, and within it are placed the large arteries which take part in the formation of the circle of Willis. Leading out from the cisterna basalis there are certain wide subarachnoid channels. Two of these are prolonged into the Sylvian fissures, and in these are accommodated the middle cerebral arteries. Anteriorly the basal cistern passes into a space in front of the optic chiasma, and from this it is continued into the great longitudinal fissure above the corpus callosum. In this subarachnoid passage the anterior cerebral arteries are lodged.

The spinal part of the subarachnoid space is a very wide interval which is partially subdivided into compartments by three incomplete septa. One of these is a mesial partition called the **septum posticum**, which connects the pia mater covering the posterior aspect of the cord with the arachnoid mater. In the upper part of the cervical region the septum posticum is imperfect, and is merely represented by some strands passing between the two membranes; in the lower part of the cervical region and in the dorsal region it becomes tolerably complete. The other two septa are formed by the **ligamenta denticulata** which spread outwards from either side of the spinal cord. These will be described with the pia mater.

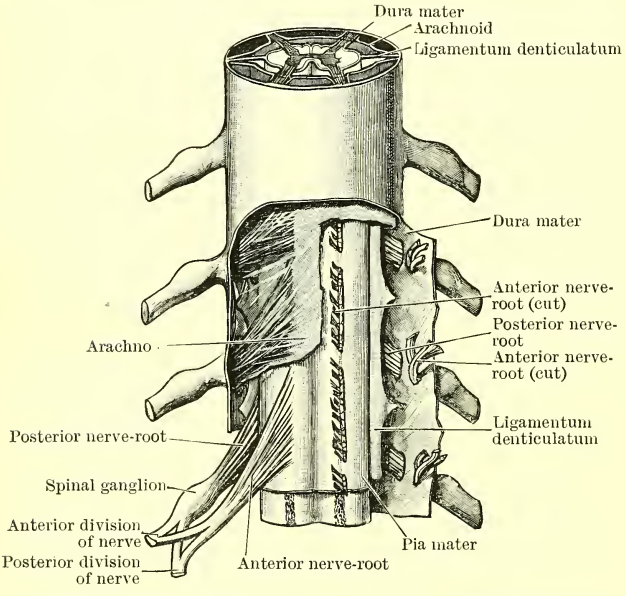


FIG. 479.—MEMBRANES OF THE SPINAL CORD, AND THE MODE OF ORIGIN OF THE SPINAL NERVES.

Pacchionian Bodies (granulationes arachnoidales).—When the surface of the dura mater is inspected after the removal of the calvaria, a number of small fleshy-looking excrescences, purplish-red in colour, are seen ranged in clusters on either side of the superior longitudinal sinus, and when this sinus is opened they are also observed protruding in considerable numbers into its interior. These are the Pacchionian bodies, and they are also found in smaller number and distinctly smaller size in connexion with other blood-sinuses, such as the lateral sinus, the

straight sinus, and the cavernous sinus. At first sight they appear to belong to the dura mater, but in reality they are projections from the arachnoidea. In the child they are exceedingly small and rudimentary, and it is only as life advances that they become large and conspicuous.

Each Pacchionian body is a bulbous protrusion of the arachnoid membrane. It is attached to the arachnoidea by a narrow pedicle, and into its interior is prolonged through this a continuation of the subarachnoid space and its characteristic meshwork. The Pacchionian bodies do not pierce the dura mater. As they push their way into a blood-sinus they carry before them a thin covering continuous with the sinus wall. On either side of the superior longitudinal sinus there are a number of irregular spaces in the dura mater which communicate with the sinus either by a small aperture or a narrow channel. These spaces are called the **parasinoidal sinuses** or the **lacunæ laterales**, and certain of the meningeal veins and some of the diploic veins open into them. Pacchionian bodies push themselves into the parasinoidal sinuses from below in such a manner that they receive a

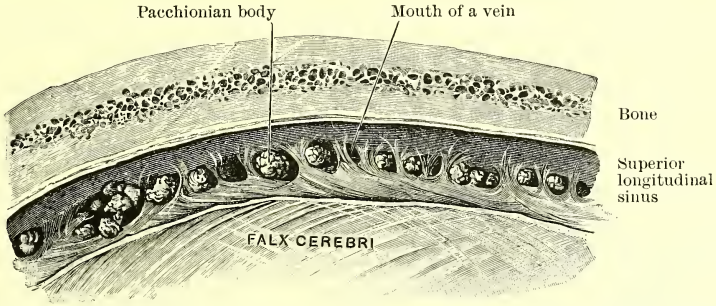


FIG. 480.—MESIAL SECTION THROUGH THE CRANIAL VAULT IN THE FRONTAL REGION. Displays a portion of the superior longitudinal sinus and the Pacchionian bodies protruding into it (enlarged).

complete covering from the layer of dura mater which forms the sinus floor. Nor does the bone escape. As the Pacchionian bodies enlarge they cause absorption of the cranial wall, and small pits are hollowed out on its deep surface for their reception. It must be clearly understood, however, that in such cases the Pacchionian body is separated from the bone by the following:—(1) A continuation round the Pacchionian body of the subdural space; (2) the thinned floor of the parasinoidal sinus; (3) the lumen of the sinus; and (4) the greatly thinned upper wall of the sinus.

The Pacchionian bodies have a special function to perform. Through them fluid can pass from the subarachnoid space into the venous sinuses with which they stand in connexion. Whenever the pressure of blood in the sinuses is lower than that of the fluid in the subarachnoid space and the ventricles of the brain, the cerebro-spinal fluid filtrates through the Pacchionian bodies into the blood-sinuses. This is not the only way that subarachnoid fluid may obtain exit. The subarachnoid space is carried outwards for a short distance on the nerves in connexion with their arachnoidal sheaths, and communicates with the lymph channels of the nerves. This connexion is more complete in the case of the olfactory, the optic, and the auditory nerves, than in other nerves. A very free communication between the subarachnoid space and the lymphatics of the nasal mucous membrane is said to exist.

THE PIA MATER.

The pia mater forms the immediate investment of the brain and cord. It is a delicate and very vascular membrane.

Pia mater encephali.—The pia mater which covers the brain is finer and more delicate than that which clothes the spinal cord. It follows closely all the inequalities on the surface of the brain, and in the case of the cerebrum it dips into each sulcus in the form of a fold which lines it completely. On the cerebellum the relation is not so intimate; it is only into the larger fissures that it penetrates in the form of folds.

The larger blood-vessels of the brain lie in the subarachnoid space. The finer twigs ramify in the pia mater before they proceed into the substance of the brain. As they enter they carry with them sheaths derived from the pia mater. When a portion of the membrane is raised from the surface of the encephalon, numerous fine processes are withdrawn from the cerebral surface. These are the blood-vessels with their sheaths, and they give the deep surface of the pia mater a rough and flocculent appearance.

As the pia mater is carried over the lower part of the roof or posterior wall of the fourth ventricle of the brain it receives the name of the **tela choroidea inferior**, and it is in connexion with this portion of the pia mater that the choroid plexuses of that cavity are developed. The tela choroidea superior or velum interpositum is a fold of pia mater which is invaginated into the brain, so that it comes to lie over the third ventricle and project in the shape of choroid plexuses into the lateral ventricles. This invagination requires special notice.

The **velum interpositum** (tela choroidea superior) is a double layer or fold of pia mater which intervenes between the body of the fornix which lies above it and the epithelial roof of the third ventricle, and the two optic thalami which lie below it. Between its two layers are blood-vessels, and some subarachnoidal trabecular tissue. In shape the velum interpositum is triangular, and the narrow anterior end or apex reaches forwards as far as the foramina of Monro. The base lies under the splenium of the corpus callosum, and here the two layers of the velum separate and become continuous with the investing pia mater on the surface of the brain by passing out through a cleft called the **transverse fissure.**

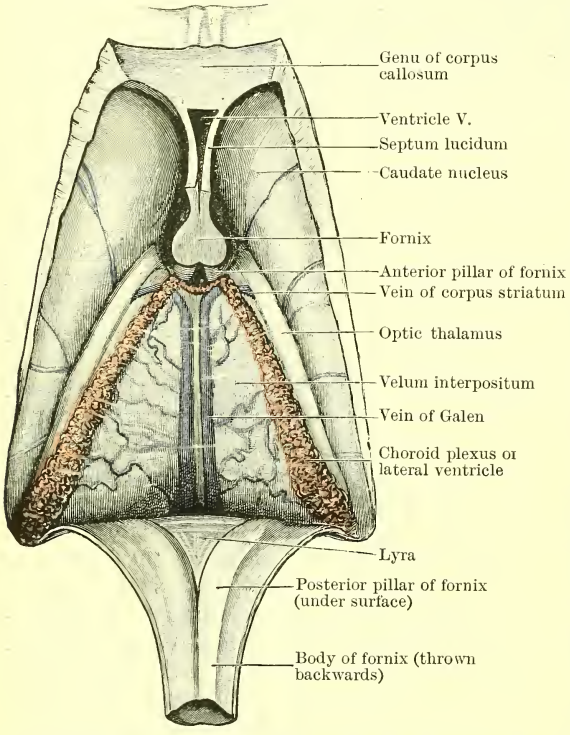


FIG. 481.—DISSECTION TO SHOW THE VELUM INTERPOSITUM, AND THE PARTS IN IMMEDIATE RELATION TO IT.

Along each lateral margin the velum interpositum is bordered by the choroid plexus of the body of the lateral ventricle, which projects into the ventricular cavity from under cover of the free lateral margin of the fornix. It should be borne in mind that the epithelial lining of the ventricle gives a complete covering to the choroid plexus. Posteriorly the choroid plexus is continuous with the similar structure in the descending horn of the ventricle, whilst in front it narrows greatly, and becomes continuous across the mesial plane with the corresponding plexus of the opposite side, behind the epithelial layer which lines the foramen of Monro. From this median junction two much smaller choroid plexuses run backwards on the under surface of the velum interpositum, and project downwards into the third ventricle. These are the choroid plexuses of the third ventricle.

The most conspicuous blood-vessels in the velum interpositum are the two **veins of Galen**, which run backwards, one on either side of the mesial plane. In front, each is formed at the apex of the fold by the union of the vein of the corpus striatum and a large vein issuing from the choroid plexus; behind, they unite to form the **vena magna Galeni**, and this pours its blood into the anterior end of the straight sinus (Fig. 477, p. 598).

The continuous cleft in the brain through which the velum interpositum and the choroid plexuses of the two descending horns of the lateral ventricles are

introduced into the interior of the brain is sometimes called the **transverse fissure**. It consists of an upper intermediate part and two lateral parts. The former passes forwards between the corpus callosum and the fornix above and the roof of the third ventricle and the optic thalami below. It is limited on either side by the epithelial covering of the choroid plexuses, which shuts out these structures from the cavity of the lateral ventricles. The lateral part is the **choroidal fissure**. This is continuous with the intermediate part, and has already been described in connexion with the descending horn of the lateral ventricle (p. 578).

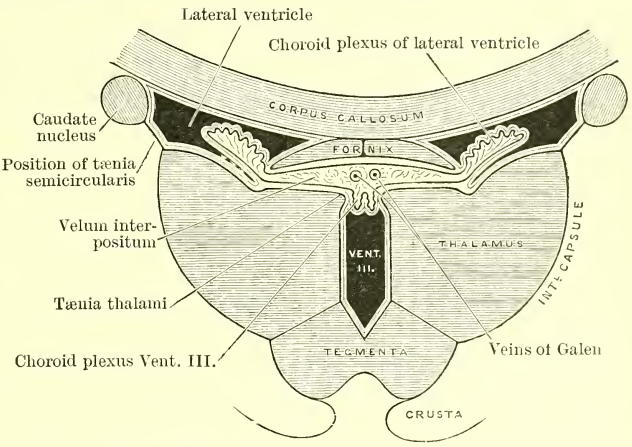


FIG. 482.—DIAGRAMMATIC CORONAL SECTION through the optic thalami, and the parts in immediate relation to them. The intermediate part of the great transverse fissure holding the velum interpositum is seen, and also the manner in which this fissure is shut out from the lateral ventricles by the epithelium which covers the choroid plexus on each side.

Pia mater spinalis.—The pia mater of the cord is thicker and denser than that of the brain. This is largely due to the addition of an outside fibrous layer, in which the fibres run chiefly in the longitudinal direction. The pia mater is very firmly adherent to the surface of the cord, and in front it sends a fold into the antero-median fissure of the cord. The septum which occupies the postero-median fissure is likewise firmly attached to its deep surface. In front of the antero-median furrow of the cord the pia mater is thickened in the form of a longitudinal glistening band, termed the **linea splendens**, which runs along the whole length of the cord, and blends with the filum terminale below. The blood-vessels of the spinal cord lie between the two layers of the pia mater.

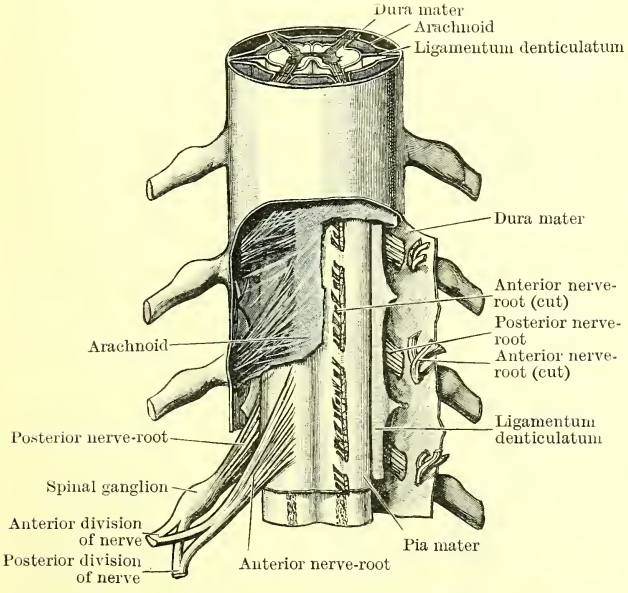


FIG. 483.—MEMBRANES OF THE SPINAL CORD, AND THE MODE OF ORIGIN OF THE SPINAL NERVES.

The nerves which leave both the brain and cord receive closely-applied sheaths from the pia mater. These blend with the connective-tissue sheaths of the nerves.

The **ligamentum denticulatum** is a strong fibrous band which stretches out like a wing from the pia mater on either side of the spinal cord, so as to connect the pia mater with the dura mater. The pial or inner attachment of the ligament extends in a continuous line between the anterior and posterior nerve-roots, from the level of the foramen magnum above to the level of the first lumbar vertebra below. Its outer margin is serrated or denticulated, and for the most part free. From twenty to twenty-two denticulations may be recognised. They occur in the intervals between the spinal nerves, and pushing the arachnoid before them, they

are attached by their pointed ends to the inner surface of the dura mater. The ligamenta denticulata partially subdivide the wide subarachnoid space in the spinal canal into an anterior and a posterior compartment. The anterior nerve-roots traverse the anterior compartment, whilst the posterior nerve-roots traverse the posterior compartment. Further, the posterior compartment is imperfectly subdivided into a right and a left lateral part by the septum posticum.

By means of the ligamenta denticulata the spinal cord is suspended in the middle of the tube of dura mater.

THE PERIPHERAL NERVES AND THE SYMPATHETIC NERVOUS SYSTEM.

By A. M. Paterson.

Arising from the brain and spinal cord respectively, the cranial and spinal nerves are responsible, collectively, for the central localisation of peripheral stimuli, or for the transmission peripherally of central impulses. The sense organs and the somatic regions of the body are in direct communication by the nerves with the brain and spinal cord. The splanchnic area, and the viscera which it contains, are governed by nerves connected with the central nervous system. By means of the sympathetic nervous system, the nerves from the cerebro-spinal system are directed to their several destinations in the splanchnic area: and connexions are effected with the roots of the nerves on the one hand, and through their peripheral branches, with the somatic region, on the other hand.

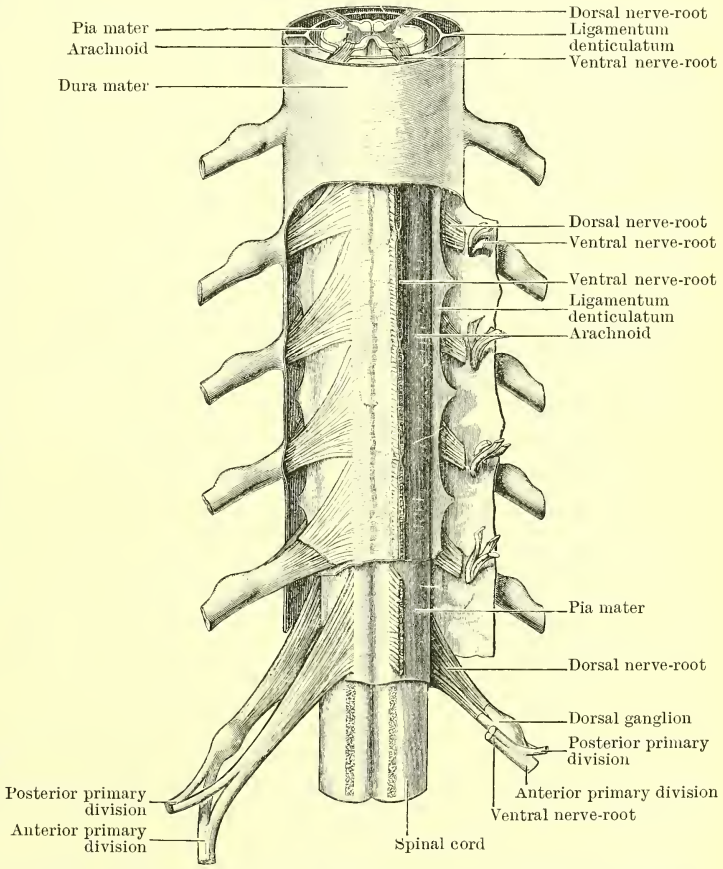


Fig. 484.—Scheme of the Arrangement of the Membranes of the Spinal Cord and the Roots of the Spinal Nerves.

THE SPINAL NERVES.

The **spinal nerves** are arranged in pairs, of which there are usually thirty-one. Each nerve arises by two roots from the spinal cord, which separately pierce the dura mater. Enclosed in a tubular investment of this membrane, the nerve emerges from the spinal canal through the intervertebral foramen, and is distributed to the trunk and limbs in a manner to be described below.

The nerves are designated **cervical, thoracic, lumbar, sacral,** and **coccygeal,** in relation to the vertebræ between which they emerge from the spinal canal. Each nerve appears below the corresponding vertebra, except the first of the cervical series,

which passes out of the spinal canal between the occipital bone and the atlas. There are thus *eight* cervical nerves (the last appearing between the seventh cervical and first thoracic vertebræ) ; there are *twelve* thoracic, *five* lumbar, *five* sacral, and *one* coccygeal nerve, all appearing below the corresponding vertebræ.

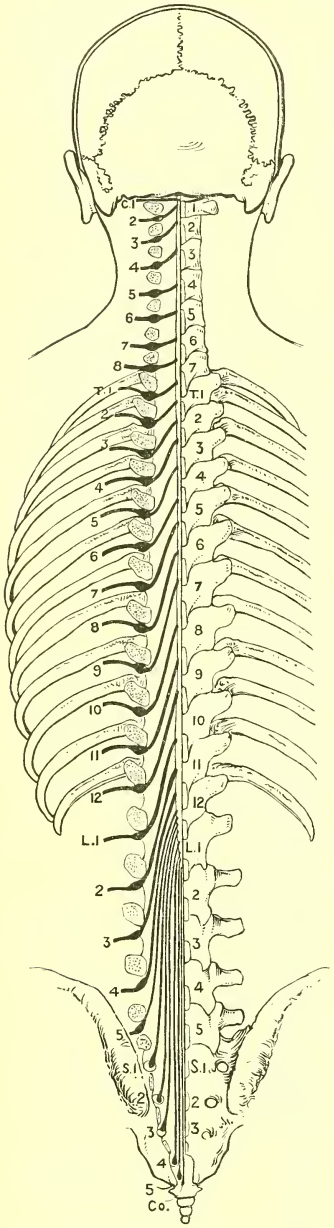


Fig. 485.—Diagrammatic Representation of the origin of the Spinal Nerves, showing the position of their roots and ganglia respectively in relation to the spinal column. The nerves are shown as thick black lines on the left side.

The thirty-first nerve is occasionally absent ; and there are sometimes one or two additional pairs of minute filaments below the thirty-first, which, however, do not emerge from the spinal canal. These are rudimentary caudal nerves.

The size of the spinal nerves varies extremely. The largest are those which take part in the formation of the great nerve-trunks for the supply of the limbs (lower cervical and first thoracic, and lower lumbar and upper sacral nerves) ; and of these the nerves destined for the lower limbs are the larger. The coccygeal nerve is the smallest of the spinal nerves ; the thoracic nerves (except the first) are much more slender than the limb nerves ; and the cervical nerves diminish in size from below upwards.

Origin of the Spinal Nerves.—Each spinal nerve is attached to the spinal cord by **two roots**, called respectively **dorsal** (posterior) and **ventral** (anterior).

The **dorsal root** is larger than the ventral root ; it contains a larger number of rootlets, and the individual rootlets are of larger size than in the ventral root. It has a vertical linear attachment to the postero-lateral sulcus of the spinal cord. The rootlets of contiguous dorsal roots are in close relation, and, in some instances, overlap. The dorsal root separates as it passes away from the cord into two bundles, both of which become connected with the inner end of a **spinal ganglion.** From the outer end of this ganglion the dorsal root proceeds to its junction with the ventral root in the intervertebral foramen.

The **spinal ganglia** are found on the dorsal roots of all the spinal nerves. (In the case of the first cervical or sub-occipital nerve, the spinal ganglion may be rudimentary or absent ; and the dorsal root itself may be wanting, or derived from the spinal accessory nerve.) They occupy the intervertebral foramina, except in the case of the sacral and coccygeal nerves, the ganglia of which lie *within* the vertebral canal : and the first and second cervical nerves, the ganglia of which lie upon the neural arches of the atlas and axis respectively. With the exception of the coccygeal ganglia they are outside the cavity of the dura mater, but are invested by the membrane. The ganglia are of ovoid form, bifurcated in some cases at their inner ends. They consist of unipolar nerve-cells, whose processes, after a very short course, divide into central (root) and peripheral (trunk) fibres. The central fibres form the portion of the root entering the spinal cord ; the peripheral fibres are continued in an outward direction from the ganglion into the spinal nerve.

Accessory spinal ganglia (ganglia aberrantia).—Between the spinal ganglion and the spinal cord small collections of cells are occasionally found on the dorsal roots, either as scattered cells or distinct ganglia. They are most frequently met with on the dorsal roots of the lumbar and sacral nerves.

The **ventral root** is smaller than the dorsal root. It arises from the anterior surface of the spinal cord (*anterior root zone*) by means of scattered bundles of nerve-fibres, which occupy a greater horizontal area and are more irregular in their arrangement than the fascicles of the dorsal root. It possesses no ganglion in its course. The rootlets sometimes overlap, and are not unfrequently connected with neighbouring rootlets above and below.

The dorsal and ventral roots, from their attachment to the spinal cord, proceed outwards in the spinal canal towards the intervertebral foramina, where they unite to form the spinal nerve. The direction of the roots of the first two nerves is upwards and outwards; the roots of the remaining nerves course obliquely downwards and outwards, the obliquity gradually increasing until, in the case of the lower lumbar, the sacral and coccygeal nerve-roots, their course is vertically downwards in the spinal canal. The collection of nerve-roots which occupies the lower part of the canal below the first lumbar vertebra, and comprises all the nerve-roots below those of the first lumbar nerve, is designated the **cauda equina.** They arise from the lumbar enlargement and conus medullaris, and surround the filum terminale of the spinal cord.

Within the spinal canal the nerve-roots are in relation with the meninges of the cord, and are separated from one another by the ligamentum denticulatum, and, in the neck, by the spinal part of the spinal accessory nerve. Each receives a covering of pia mater, continuous with the neurilemma; the arachnoid invests each root as far as the point where it meets with the dura mater; and each root pierces the dura mater separately. The two roots are thereafter enclosed in a single tubular sheath of dura mater, in which is included the spinal ganglion of the dorsal root. The spinal nerve thus formed lies in the intervertebral foramen, except in the case of the first two cervical and the sacral and coccygeal nerves.

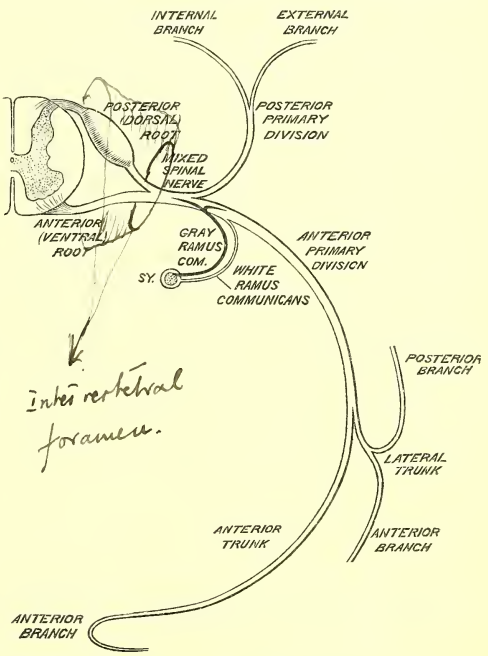


FIG. 486.—SCHEME OF THE DISTRIBUTION OF A TYPICAL SPINAL NERVE.

Divisions of a Spinal Nerve.—After emerging from the intervertebral foramen the nerve immediately divides into two primary divisions, named respectively the **posterior** and **anterior primary divisions.** Just before its division each nerve gives off a minute **recurrent branch,** which re-enters the vertebral canal after effecting a junction with a branch from the sympathetic cord, and is distributed to the spinal cord and its membranes.

The **posterior** and **anterior primary divisions** of the spinal nerve are responsible for the innervation of the skeletal muscles and the skin covering the trunk and limbs. They are thus, properly speaking, the somatic branches of the spinal nerve.

In relation to certain of the nerves, a series of much smaller branches exist which are connected with the sympathetic system (Fig. 486, *SY*), in a way to be described later. These constitute the **white rami communicantes,** and may be termed the **visceral divisions** of the spinal nerves. They are derived from the anterior primary divisions of the nerves, and receive their fibres mainly from the ventral roots, though, at least in the case of certain nerves, from the dorsal roots as well. These nerves are directed inwards from the intervertebral foramen over the vertebral column, and, becoming connected with the sympathetic cord, convey spinal fibres to the organs and tissues in the splanchnic area.

The posterior and anterior primary divisions of the nerves contain fibres from

both dorsal and ventral roots. Indeed, each root can be seen, on removal of its sheath, to divide into two portions, of which one portion enters into the formation of the posterior, the other into the formation of the anterior primary division. The posterior primary divisions, with the exception of the first two, are smaller than the anterior primary divisions; and they are, generally speaking, responsible for the innervation of the skin and muscles of the back. They do not supply the muscles of the limbs; although in their cutaneous distribution they are prolonged on to the back of the head, the shoulder, and the buttock. They form two small plexuses —the **posterior cervical** and the **posterior sacral plexuses**. The anterior primary divisions are, with the exception of the first two cervical nerves, much larger than the posterior primary divisions. They supply the sides and fore-parts of the body, the limbs, and the perineum. For the most part they have a complicated arrangement. The thoracic or intercostal nerves alone have a simple mode of distribution; the other nerves give rise to the three great **plexuses—cervical, brachial,** and **lumbo-sacral**.

Distribution of the Spinal Nerves.—The distribution, like the origin of the posterior and anterior primary divisions of the spinal nerves, presents primarily and essentially a segmental arrangement, masked and in some cases obliterated by developmental changes which have occurred in the parts supplied. In no region can a single nerve be traced to a complete segment. In the trunk between the limbs the nearest approach to a complete girdle is formed by such a nerve as the sixth thoracic nerve. In its cutaneous distribution it forms a perfect belt, the nerve by its posterior and anterior primary divisions supplying a distinctly segmental area from the middle line of the trunk behind to the sternum in front. Its muscular distribution, also, is almost perfectly segmental. The anterior primary division supplies, unaided, the intercostal muscles of the segment in which it lies. The posterior primary division supplies muscles in the back, not, however, in a strictly segmental manner, on account of the fact that the segmental myotomes have fused together in the back to give rise to complex longitudinal muscles, which are together supplied by the series of muscular branches derived from the posterior primary divisions of contiguous nerves. In other regions greater changes cause more marked deviations from a simple segmental type of distribution and give rise to the various plexuses, by which the trunk, and more particularly the limbs, are innervated.

POSTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES.

The posterior primary divisions of the spinal nerves are distributed generally to the skin of the back of the trunk, the back of the head, the shoulder and the buttock, and to the longitudinal muscles of the back, but not to the muscles of the limbs.

Each posterior primary division divides as a rule into two parts, an **internal** and an **external trunk** (Fig. 486, p. 609). In the upper half of the body the internal trunks generally supply the cutaneous branches, while the external trunks are purely muscular nerves. In the lower part of the body the opposite is the case: the external trunks provide the cutaneous nerves and the internal trunks are distributed entirely to muscles. The cutaneous branches have a different course in the two cases. In the upper half of the back they course inwards and backwards beneath and among the muscles to within a short distance of the spinous processes of the vertebræ, close to which they become superficial. They then extend outwards in the superficial fascia. In the lower half of the back the cutaneous nerves are directed downwards and outwards among the muscles, and become superficial at a greater distance from the middle line.

CERVICAL NERVES.

First Cervical Nerve (n. sub-occipitalis).—It has already been pointed out that the dorsal root of this nerve may be rudimentary, or even absent altogether. Its posterior primary division is larger than the anterior primary division; it does not divide into internal or external branches, and it does not directly supply any cutaneous branch.

Passing backwards in the space between the occipital bone and the posterior arch of the atlas, the nerve occupies the sub-occipital triangle, and is placed below and behind the vertebral artery, and under cover of the complexus muscle. It supplies the following branches:—

(*a*) **Muscular branches** to the complexus, recti capitis postici, major and minor, and obliqui, superior and inferior.

(*c*) A **communicating branch** descends to join the second cervical nerve.

The communicating branch may arise in common with the nerve to the obliquus inferior, and reach the second cervical nerve by piercing or passing over or beneath the obliquus inferior. Or it may accompany the nerve to the complexus, and communicate with the great occipital nerve, after piercing that muscle.

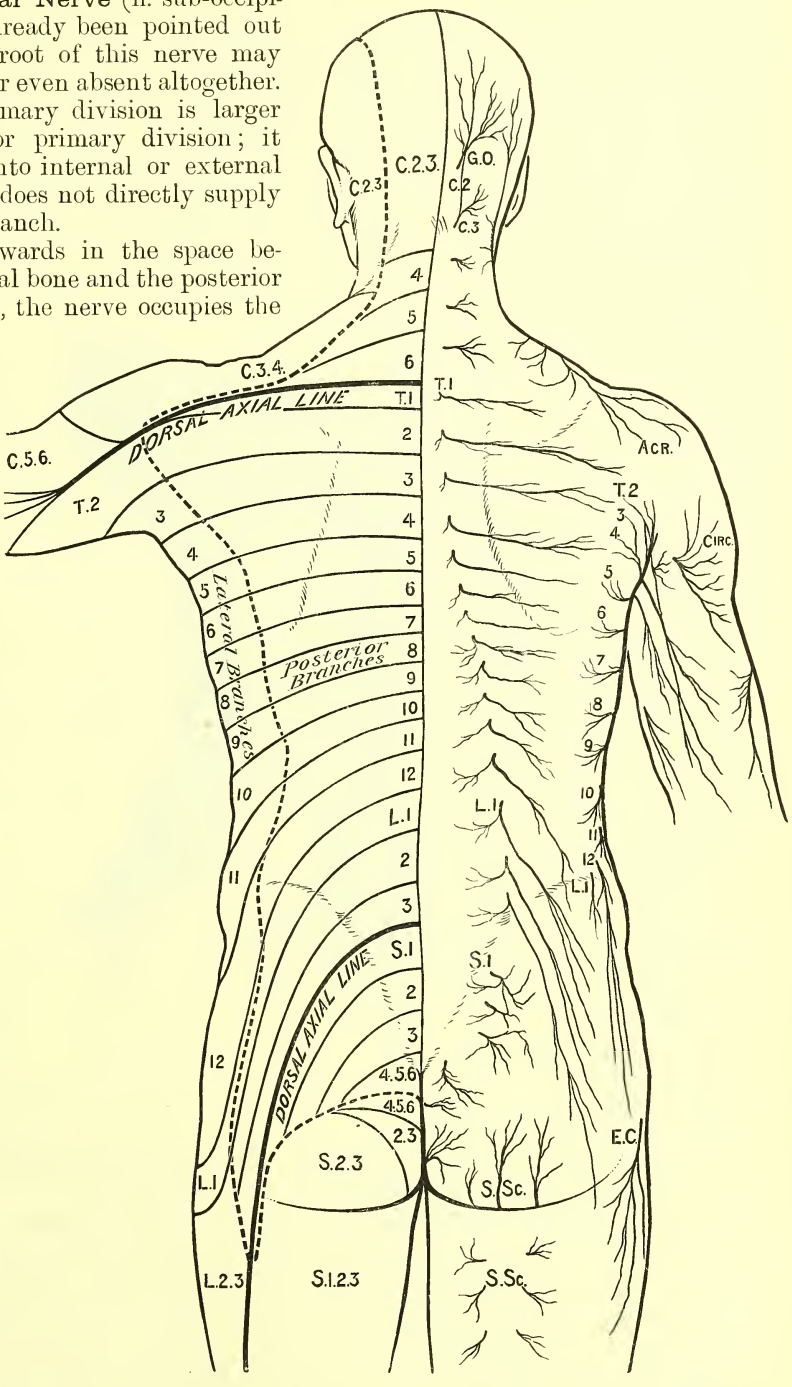


FIG. 487.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE BACK OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.O (C.2), Great occipital; C.3, Least occipital; T.1 *et seq.*, Posterior primary divisions of thoracic nerves; L.1 *et seq.*, Posterior primary divisions of first three lumbar nerves; S.1 *et seq.*, Posterior primary divisions of sacral nerves; Acr, Acromial branches from cervical plexus; T.2-12, Lateral branches of thoracic nerves; Circ, Cutaneous branches of circumflex nerve; L.1, Iliac branch of ilio-hypogastric nerve; E.C, External cutaneous nerve; S.Sc, Small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

Second Cervical Nerve.—The posterior primary division of this nerve is larger than the corresponding anterior primary division. It passes backwards between the atlas and axis, and in the interval between the obliquus inferior and the semispinalis colli muscles, under cover of the complexus muscle. In this situation the nerve gives off several small muscular and communicating branches. The main trunk, after piercing the complexus and trapezius muscles, accompanies the occipital artery to the scalp as the **great occipital nerve** (n. occipitalis major). This is the chief cutaneous nerve for the back part of the scalp. It enters the superficial fascia at the level of the superior curved line of the occipital bone and about an inch from the external occipital protuberance. Ramifying over the surface, it supplies the skin of the scalp as far as the vertex. It *communicates* on

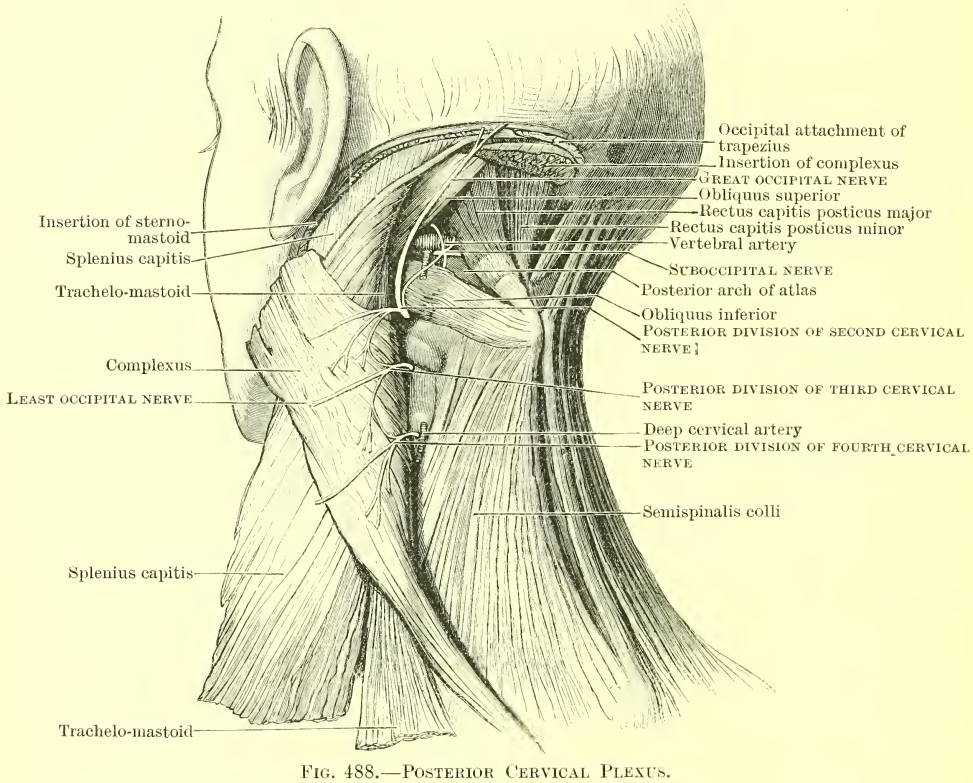


FIG. 488.—POSTERIOR CERVICAL PLEXUS.

the scalp with the following nerves: great auricular, small occipital, posterior auricular, and least occipital.

The **muscular branches** of the second cervical nerve are destined for the complexus, obliquus inferior, semispinalis colli, and multifidus spinæ.

Its **communicating branches** form the **posterior cervical plexus.** Descending over the posterior arch of the atlas is a branch from the sub-occipital nerve which forms a loop or network with a corresponding branch of the second nerve. From this loop twigs are supplied to the surrounding muscles. A similar loop is formed by a communication between branches of the second and third nerves, from which muscles are also supplied. Occasionally an additional loop is formed between branches of the third and fourth nerves.

Third Cervical Nerve.—This is much smaller than the second nerve. Near its origin it forms a loop of communication with the second, and it may give off a similar communicating branch to the fourth nerve. The main trunk divides into internal cutaneous and external muscular branches. The external muscular branch enters contiguous muscles; the internal cutaneous branch passes backwards and inwards, and becomes superficial as the **third** or **least occipital nerve** (n. occipitalis minimus), close to the middle line of the neck. It supplies fine branches to the neck and scalp, and communicates with the great occipital nerve.

The **fourth, fifth, and sixth cervical nerves** are still smaller. Beneath the complexus each divides into external muscular and internal cutaneous branches. The muscular branches supply neighbouring muscles; the cutaneous branches are small nerves, which, passing backwards, become superficial close to the middle line. They supply the skin of the back of the neck. The sixth is the smallest, and its cutaneous branch is minute, and may be absent altogether. In certain cases the fourth nerve forms, with the third, a loop of communication from which muscles are supplied.

Seventh and Eighth Cervical Nerves.—These are the smallest of the posterior primary divisions of the cervical nerves. They give off ordinarily no cutaneous branches, and end in the deep muscles of the back.

THORACIC NERVES.

The posterior primary division of each thoracic nerve divides into an **internal** and **external branch.** In the case of the upper six thoracic nerves the internal branches are chiefly distributed as cutaneous nerves,—only giving off small muscular branches—while the external branches are wholly muscular in their distribution; in the case of the lower six thoracic nerves the opposite is the case. In all cases the muscular branches serve to innervate the longitudinal muscles of the back. The distribution of the cutaneous branches is different in the upper and lower part of the back. The *upper six* or *seven* thoracic nerves innervate the skin of the scapular region. The **internal cutaneous branches**, after passing backwards from their origin among the dorsal muscles, reach the surface near the spines of the vertebræ and are directed almost horizontally outwards over the vertebral border of the scapula. The first is small; the second is very large and reaches to the acromion process. The rest diminish in size, from above downwards, and become more and more oblique in direction. The **external cutaneous branches** of the *lower five* or *six* thoracic nerves are directed from their origin obliquely downwards and outwards among the parts of the erector spinæ muscle. Becoming cutaneous by piercing the latissimus dorsi at some distance from the middle line, they supply the skin of the back in the lower part of the chest and loin, the lowest nerves (eleventh and twelfth) reaching over the iliac crest on to the buttock. The lower nerves often subdivide into two branches before or after their emergence from the latissimus dorsi muscle.

LUMBAR NERVES.

First three Lumbar Nerves.—The posterior primary divisions of the first three lumbar nerves subdivide into internal and external branches, in the same way as the lower thoracic nerves. The internal branches are muscular and innervate the deep muscles of the back. The external branches are chiefly cutaneous. They are directed obliquely downwards and outwards among the fibres of the erector spinæ and become superficial by piercing the vertebral aponeurosis, just above the iliac crest and a short distance in front of the posterior iliac spine. They are then directed downwards in the superficial fascia of the buttock, and supply a lengthy strip of skin, extending from the middle line above the iliac crest to a point below and behind the great trochanter of the femur.

The **fourth and fifth lumbar nerves** (like the last two cervical nerves) usually supply only muscular branches to the longitudinal muscles of the back. The fifth nerve in many cases sends a minute branch to form a loop of connexion with the posterior primary division of the first sacral nerve (**posterior sacral plexus**).

SACRAL AND COCCYGEAL NERVES.

The posterior primary divisions of the sacral nerves issue from the posterior sacral foramina. As in the case of the thoracic and lumbar nerves, the upper sacral nerves differ from the lower in their distribution.

The **first three sacral nerves** supply internal muscular branches for the multifidus spinæ, and external cutaneous branches which pierce the fibres of the sacro-sciatic ligament and the gluteus maximus muscle, and supply the skin over

the back of the sacrum and contiguous part of the buttock, giving rise to the posterior sacral plexus.

The **posterior sacral plexus** consists, like the posterior cervical plexus, of loops or plexiform communications over the back of the sacrum between the posterior primary divisions of the first three sacral nerves, to which are frequently joined branches of the last lumbar nerve and fourth sacral nerve. From these loops branches proceed to supply the multifidus spinæ muscle; others, piercing the great sacro-sciatic ligament, form secondary loops beneath the gluteus maximus muscle. From the secondary loops, two or more cutaneous branches arise, which, after traversing the muscle, supply the skin over the sacrum and inner part of the buttock.

Posterior Sacro-coccygeal Nerve.—The posterior divisions of the fourth and fifth sacral nerves do not divide into internal and external branches. They unite together to form a cord which, descending behind the coccyx, receives the minute posterior primary division of the coccygeal nerve. The union of the three nerves constitutes the **posterior sacro-coccygeal nerve**, which, after perforating the sacro-sciatic ligament, is distributed to the skin in the neighbourhood of the coccyx. It supplies no muscles. This nerve is the representative of the **superior caudal trunk** of tailed animals.

Morphology of the Posterior Primary Divisions.

There are several points of morphological interest in relation to the posterior primary divisions of the spinal nerves.

1. **Muscular Distribution.**—In their muscular distribution they are strictly limited to the longitudinal muscles of the back: namely, those associated with the axial skeleton alone.

2. **Cutaneous Distribution.**—Their cutaneous distribution represents two points of interest.

A. In the first place, while the skin of the back is supplied in a regularly segmental manner by the several nerves, certain of them fail to reach the surface at all. The absence of a cutaneous branch from the sub-occipital nerve may be due either to the absence of a perfect dorsal root, or to its communication with the second nerve. The other nerves, which do not usually supply the skin, are the seventh and eighth cervical, and the fourth and fifth lumbar nerves. These nerves are placed in the centre of regions in which the upper and lower limbs are developed. They are minute nerves, while the corresponding anterior primary divisions are among the largest of the spinal nerves. Thus, opposite the centre of each limb, posteriorly, there is a hiatus in the segmental distribution of the posterior primary divisions of the spinal nerves to the skin of the shoulder and buttock, attributable to the formation of the limbs, and the extension into them of the greater part of the nerves of the region. This gap, in the case of the upper limb, commences at the level of the vertebra prominens; in the case of the lower limb it commences opposite the level of the posterior superior iliac spine. It can be continued on to each limb as a hypothetical area (the **dorsal axial line**), which indicates the area of contact (and overlapping) of cutaneous nerves not in strictly numerical sequence. Thus, in the region of the shoulder, the sixth (or fifth) cervical nerve innervates an area of skin adjoining that supplied by the first thoracic nerve; in the region of the buttock the third lumbar nerve supplies an area contiguous with that supplied by the first sacral nerve.

B. The cutaneous branches of the posterior primary divisions of the spinal nerves differ from the muscular branches in respect of their penetration into regions beyond those supplied by their motor roots. The cutaneous branches, in regions where outgrowths or extensions from the trunk have occurred, follow these extensions; and, in consequence, supply skin covering parts which do not belong to segments represented by the nerves in question. Thus the second and third cervical nerves (great and least occipital) are drawn upwards so as to supply the posterior part of the *scalp*; the upper thoracic nerves are drawn outwards over the *scapular region*; the upper lumbar and sacral nerves supply the skin of the *buttock*; and the sacro-coccygeal nerve forms a rudimentary *caudal nerve*.

3. **Plexuses.**—The plexuses formed by the posterior primary divisions of the upper cervical and upper sacral nerves are the simplest met with in the human body. The posterior cervical plexus is one from which muscular branches are supplied; the posterior sacral plexus is mainly concerned in producing cutaneous offsets. In the case of the **posterior cervical plexus** the loops of communication between the first three or four cervical nerves result in the formation of a series of nerves for the supply of the semispinalis, complexus, and other muscles, which bring into contact with these muscles, simultaneously, a considerable area of the spinal cord, and provide a combined and simultaneous innervation for the several parts of each muscle. In the case of the **posterior sacral plexus**, the formation of loops between the nerves results in the innervation of any given spot in the cutaneous area supplied from these loops by more than one spinal nerve. As has been said already, the cutaneous nerves, even without the formation of plexuses, overlap in their cutaneous distribution. The formation of a plexus causes a more intimate union of neighbouring spinal nerves, so that stimulation of the surface affects a wider area in the spinal cord than if the nerves passed separately to it from the surface. While segmentation becomes less obvious, increased co-ordination is effected both of movement and sensation.

ANTERIOR PRIMARY DIVISIONS OF THE SPINAL NERVES.

The anterior primary divisions of the spinal nerves, are, with the exception of the first two cervical nerves, much larger than the corresponding posterior primary divisions. Composed of elements of both dorsal and ventral roots, each nerve separates from the posterior primary division on emerging from the intervertebral foramen, and, proceeding outwards, is distributed to structures on the lateral and anterior aspects of the body,—including the limbs.

Each nerve is joined near its origin by a **gray ramus communicans** from the sympathetic gangliated cord; and in the case of certain thoracic, lumbar, and sacral nerves, the anterior primary division gives off a delicate bundle of fibres, which forms the **white ramus communicans** of the sympathetic cord. That part of the spinal nerve which is distributed to the body wall and limbs may be termed **somatic**; the small white ramus communicans, innervating the structures in the splanchnic area, may be termed the **visceral** or **splanchnic** part of the spinal nerve.

The anterior primary divisions of the spinal nerves are only,

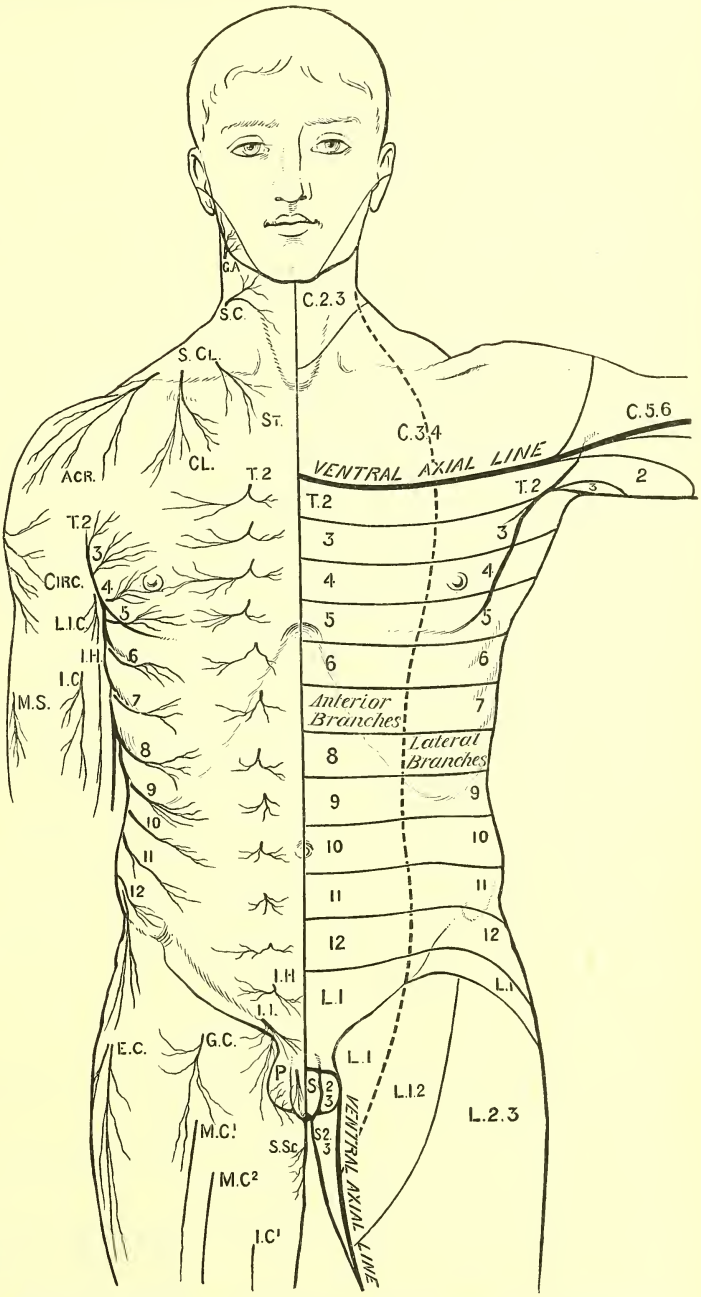


Fig. 489.—The Distribution of Cutaneous Nerves on the Front of the Trunk.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A, Great auricular nerve; S.C, Superficial cervical nerve; S.Cl, Supra-clavicular nerves; Acr, Acromial; Cl, Clavicular; St, Sternal; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; Circ, Cutaneous branch of circumflex nerve; L.I.C, Lesser internal cutaneous nerve; I.H, Intercosto-humeral; I.C, Internal cutaneous; M.S, Cutaneous branch of musculo-spiral nerve; E.C, External cutaneous nerves; G.C, Genito-crural nerve; M,C¹ ², Middle cutaneous nerves; I.C¹, Branch of internal cutaneous nerve; P, Branches of pudic nerve; S.Sc, Branches of small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

in certain cases, distributed in a regular segmental manner. Except in the case of the thoracic nerves, the anterior primary divisions combine to form the three great **plexuses**—cervical, brachial, and lumbo-sacral—and their arrangement and distribution is rendered exceedingly complex.

A **thoracic nerve**, such as the fifth or sixth, may be regarded as a type to illustrate the mode of distribution of the anterior primary divisions of the spinal nerves (Fig. 486, p. 609). It occupies an intercostal space; near its origin it possesses *gray* and *white rami communicantes*; it courses through the interval between the intercostal muscles; it supplies branches to these muscles and gives off, when it reaches the side of the chest, a *lateral branch*, which, after supplying small muscular branches, pierces the external intercostal muscle, and is distributed to an area of skin over the lateral part of the trunk, contiguous dorsally with a similar area, innervated by the cutaneous branches of the posterior primary division of the same nerve. The lateral branch generally subdivides into a smaller *posterior* and a larger *anterior trunk*, as it pierces the muscles clothing the wall of the chest. The anterior primary division of the nerve then pursues its course obliquely forwards to the side of the sternum, where, after piercing the pectoral muscles, it appears superficially as the *anterior terminal cutaneous branch*. This supplies an area of skin continuous with that supplied by the anterior part of the lateral branch of the same nerve. Such a nerve thus supplies, by means of its lateral and anterior

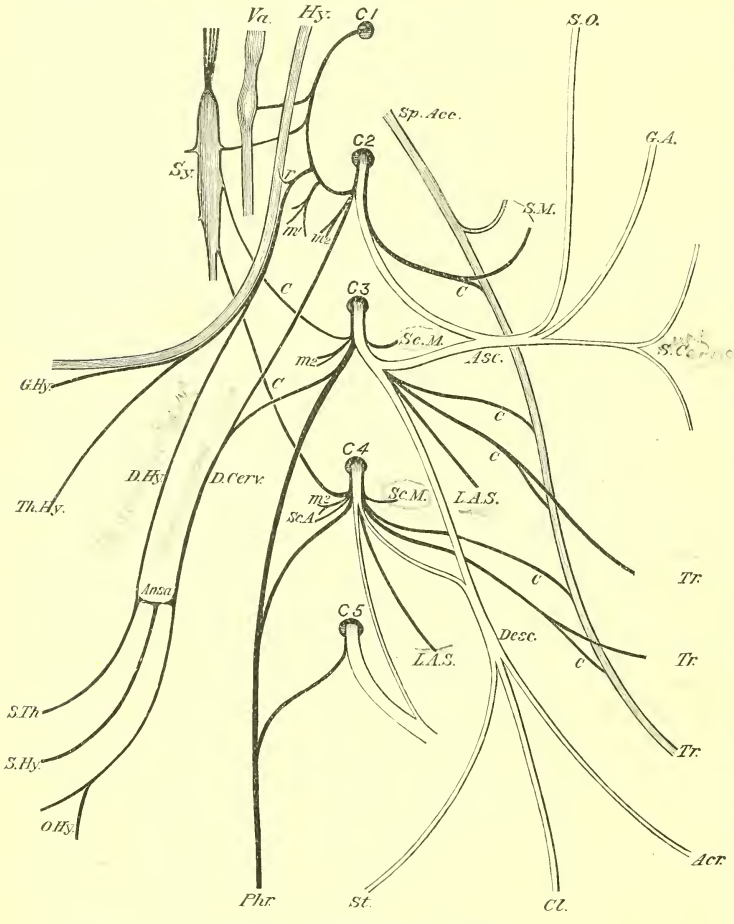


FIG. 490.—THE CERVICAL PLEXUS.

Superficial Division.

Ascending branches (Asc.)—
- S.O. Small occipital.
- G.A. Great auricular.
- S.C. Superficial cervical.

Descending (supra-clavicular) branches (Desc.)—
- Acr. Acromial.
- Cl. Clavicular.
- St. Sternal.

Deep Division.

External branches—
Communicating (C.) to spinal accessory nerve (Sp. Acc.).
Muscular—
- S.M. Sterno-mastoid.
- Tr. Trapezius.
- L.A.S. Levator anguli scapulæ.
- Sc.M. Scalenus medius.

Internal branches—
Communicating to
- Hy. Hypoglossal.
- Va. Vagus.
- Sy. Sympathetic ganglion.
- D.Cerv. Descendens cervicis.

Muscular—
- M^1. Rectus capitis anticus minor, and lateralis.
- M^2. Longus colli, and rectus capitis anticus major.
- Sc.A. Scalenus anticus.
- Phr. Phrenic nerve.
- G.Hy. Nerve to genio-hyoid.
- Th.Hy. Nerve to thyro-hyoid.
- D.Hy. Descendens hypoglossi.
- Ansa. Ansa hypoglossi.
- S.Th. Nerve to sterno-thyroid.
- S.Hy. Nerve to sterno-hyoid.
- O.Hy. Nerves to omo-hyoid.

branches, an area of skin which (with the area supplied by the cutaneous branch of its posterior primary division) forms a continuous and uninterrupted belt, extending from the middle line behind to the middle line in front. The lateral and anterior branches of the nerve innervate in their course the intercostal and other muscles, to be afterwards mentioned in detail.

CERVICAL NERVES.

The anterior primary divisions of the cervical nerves, together with parts of the first and second thoracic nerves, are distributed to the head, neck, and upper extremity. The first four cervical nerves, by means of the **cervical plexus**, innervate the neck; the last four cervical nerves, together with a large part of the first thoracic nerve, through the **brachial plexus**, supply the upper limb. The second thoracic nerve may contribute a trunk to this plexus, and always assists in the innervation of the arm.

THE CERVICAL PLEXUS.

The anterior primary divisions of the first four cervical nerves are concerned in forming the cervical plexus. Each nerve emerges from the spinal canal behind the vertebral artery. Each is joined on its emergence from the intervertebral foramen, at the side of the vertebral column, by a **gray ramus communicans** from the superior cervical ganglion of the sympathetic. In the neck the cervical nerves are concealed by the sterno-mastoid muscle; in front lies the rectus capitis anticus major, and behind are the scalenus medius, and (behind the first or sub-occipital nerve) the rectus capitis lateralis. The cervical plexus is constituted by the combination of these nerves in an irregular series of loops under cover of the sterno-mastoid muscle.

From these loops the branches of distribution arise, as (*a*) **cutaneous branches** to the head, neck, and shoulder; (*b*) **muscular branches** to the muscles of the neck and the diaphragm; and (*c*) **communicating branches** to the vagus, spinal accessory, hypoglossal, and sympathetic nerves.

For convenience of description, the nerves derived from the plexus may be classified as follows:—

I. Superficial (cutaneous) Branches—

A. **Ascending Branches** (C. 2, 3).
- Small occipital,
- Great auricular,
- Superficial cervical.

B. **Descending (supra-clavicular) Branches** (C. 3, 4).
- Acromial,
- Clavicular,
- Sternal.

II. Deep (muscular and communicating) Branches—

A. **External Branches.**
1. Muscular branches to
 - Sterno-mastoid (C. 2),
 - Trapezius (C. 3, 4),
 - Levator anguli scapulæ (C. 3, 4),
 - Scaleni (medius and posticus) (C. 3, 4).
2. Communicating branches to
 - Spinal accessory nerve (C. 2, 3, 4).

B. **Internal Branches.**
1. Muscular to
 - Prevertebral muscles (C. 1, 2, 3, 4),
 - Infra-hyoid muscles (C. 1, 2, 3) (ansa hypoglossi),
 - Diaphragm (C. 3, 4) (phrenic nerve).
2. Communicating branches to
 - Vagus nerve (C. 1, 2),
 - Hypoglossal nerve (C. 1, 2),
 - C. Hypoglossi (C. 2, 3),
 - Sympathetic (C. 1, 2, 3, 4).

The second, third, and fourth cervical nerves are the chief nerves engaged in forming the plexus. The first cervical nerve only enters into the formation of a small part—the internal portion of the deep part of the plexus.

Superficial Cutaneous Branches.—These nerves, six in number, are entirely cutaneous. They radiate from the plexus, and appear in the posterior triangle of

the neck at the posterior border of the sterno-mastoid muscle. They are divisible into two series, the one **ascending**: small occipital, great auricular, and superficial cervical; the other **descending** (supra-clavicular): sternal, clavicular, and acromial.

Ascending Branches.—The **small occipital nerve** (n. occipitalis minor) is variable in size and is sometimes double. Its origin is from the second and third cervical nerves (more rarely from the second only). It extends backwards beneath the sterno-mastoid, and then upwards along its posterior border. Piercing the deep fascia near the apex of the posterior triangle, it divides into **auricular, mastoid,** and **occipital branches,** and supplies small **cervical branches** to the upper part of the neck. The auricular branch supplies the skin of the deep surface of the pinna; the mastoid and occipital branches supply the scalp. The nerve communicates on the scalp with the great occipital and great auricular nerves, and with the posterior auricular branch of the facial nerve.

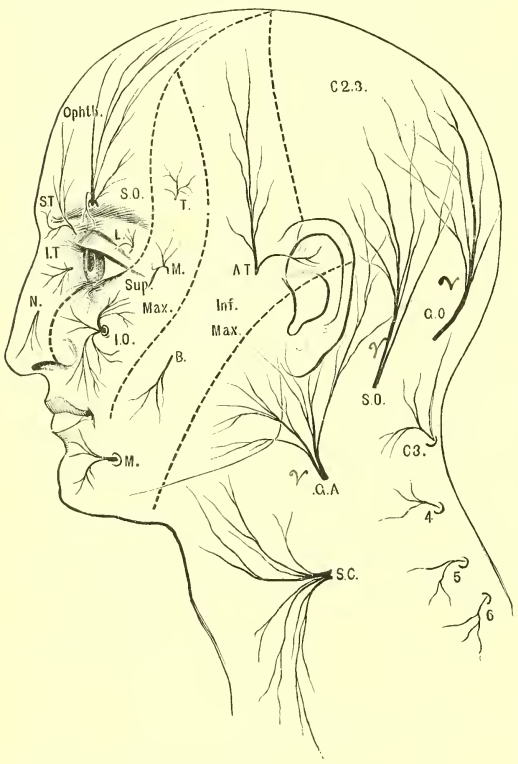


Fig. 491.—Distribution of Cutaneous Nerves to the Head and Neck.

Ophth, Ophthalmic division of the fifth nerve; S.T, Supra-trochlear branch; S.O, Supra-orbital branch; I.T, Infra-trochlear branch; L, Lachrymal branch; N, External nasal branch; Sup.Max, Superior maxillary division; T, Temporal branch; M, Malar branch; I.O, Infra-orbital branch; Inf.Max, Inferior maxillary division; A.T, Auriculo-temporal branch; B, Buccal branch; M, Mental branch; C.2, 3, Branches of the second and third cervical nerves; G.O, Great occipital nerve; S.O, Small occipital nerve; G.A, Great auricular nerve; S.C, Superficial cervical nerve; C.3, Least occipital nerve; 4, 5, 6, Posterior primary divisions of 4th, 5th, and 6th cervical nerves.

The **great auricular nerve** (n. auricularis magnus) is the largest of the cutaneous branches. It arises from the second and third cervical nerves (or, more rarely, from the third alone). Winding round the posterior border of the sterno-mastoid muscle, it courses vertically upwards towards the ear. In this course it crosses the sterno-mastoid muscle obliquely and is covered by the platysma myoides. Before arriving at the ear it subdivides into mastoid, auricular, and facial branches. The **mastoid branches** ascend over the mastoid process and supply the skin of the scalp behind the ear, communicating with the small occipital and posterior auricular nerves. The **auricular branches** ascend to the ear and supply the lower part of the pinna on both aspects; they communicate with the same nerves. The **facial branches,** passing over the angle of the jaw and through the substance of the parotid gland, supply the skin of the cheek over the lower part of the masseter muscle and the parotid gland. They communicate with branches of the facial nerve in the parotid gland.

The **superficial cervical nerve** (n. cutaneus colli) arises from the second and third cervical nerves. It winds round the posterior border of the sterno-mastoid muscle, and crosses the muscle to reach the anterior triangle, under cover of the platysma myoides muscle and the external jugular vein. It divides near the anterior edge of the sterno-mastoid muscle into upper and lower branches, which are distributed through the platysma myoides to the skin covering the anterior triangle of the neck. The upper branches communicate freely beneath the platysma myoides with the infra-mandibular branch of the facial nerve.

Descending (supra-clavicular) Branches.—By the union of two roots derived from the third and fourth cervical nerves a considerable trunk is formed, which

emerges from under cover of the sterno-mastoid muscle and extends obliquely downwards through the lower part of the posterior triangle of the neck. It subdivides into radiating branches—**sternal, clavicular,** and **acromial**—which pierce the deep fascia of the neck above the clavicle, and are distributed to the skin of the lower part of the side of the neck, the front of the chest, and the shoulder. The **sternal branches** (rami supra-sternales) are the smallest. Passing over the inner end of the clavicle, they supply the skin of the neck and chest as far down as the manubrio-sternal joint. The **clavicular branches** (rr. supra-claviculares) pass over the middle third of the clavicle, beneath the platysma, and can be traced

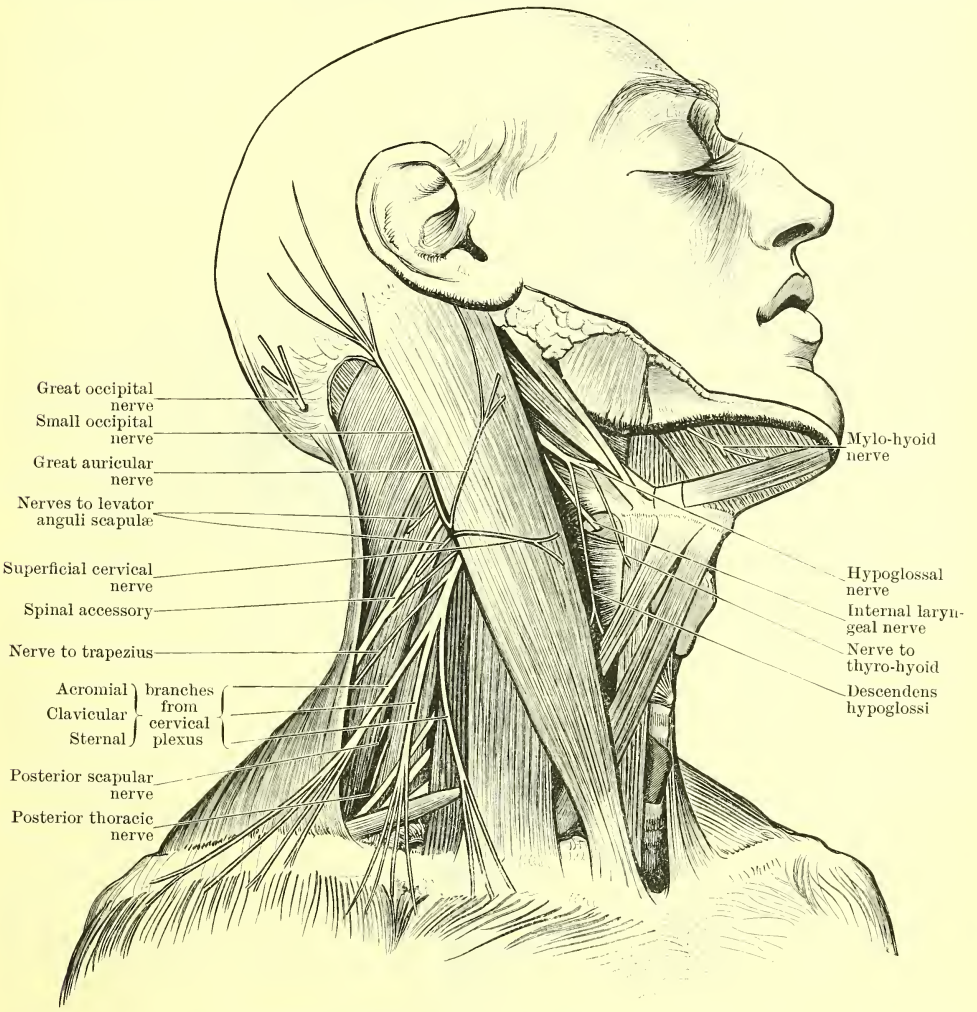


FIG. 492.—THE TRIANGLES OF THE NECK (Nerves).

as low as the nipple. The **acromial branches** (rr. supra-acromiales) pass over or through the insertion of the trapezius muscle, and over the outer third of the clavicle, to the shoulder, where they supply the skin as far down as the lower third of the deltoid muscle.

Deep Branches.—The deep branches of the cervical plexus are naturally separated into an **external** and an **internal set** by their relation to the sterno-mastoid muscle. Beneath the muscle, the external branches are directed outwards towards the posterior triangle, the internal branches inwards towards the anterior triangle.

The **external branches** consist of muscular and communicating nerves, which for the most part occupy the posterior triangle.

The **muscular branches** are the following: (1) To the *sterno-mastoid,* from the second cervical nerve. This enters the muscle on its deep surface and communicates

with the spinal accessory nerve. (2) To the *trapezius,* from the third and fourth cervical nerves. These nerves cross the posterior triangle and end in the trapezius, after having communicated with the spinal accessory nerve, in the posterior triangle, and beneath the muscle. (3) To the *levator anguli scapulæ,* from the third and fourth cervical nerves. Two independent branches enter the outer surface of the muscle in the posterior triangle. (4) To the *scaleni* (medius and posticus), from the third and fourth cervical nerves.

The **communicating branches,** already mentioned, are three in number. They

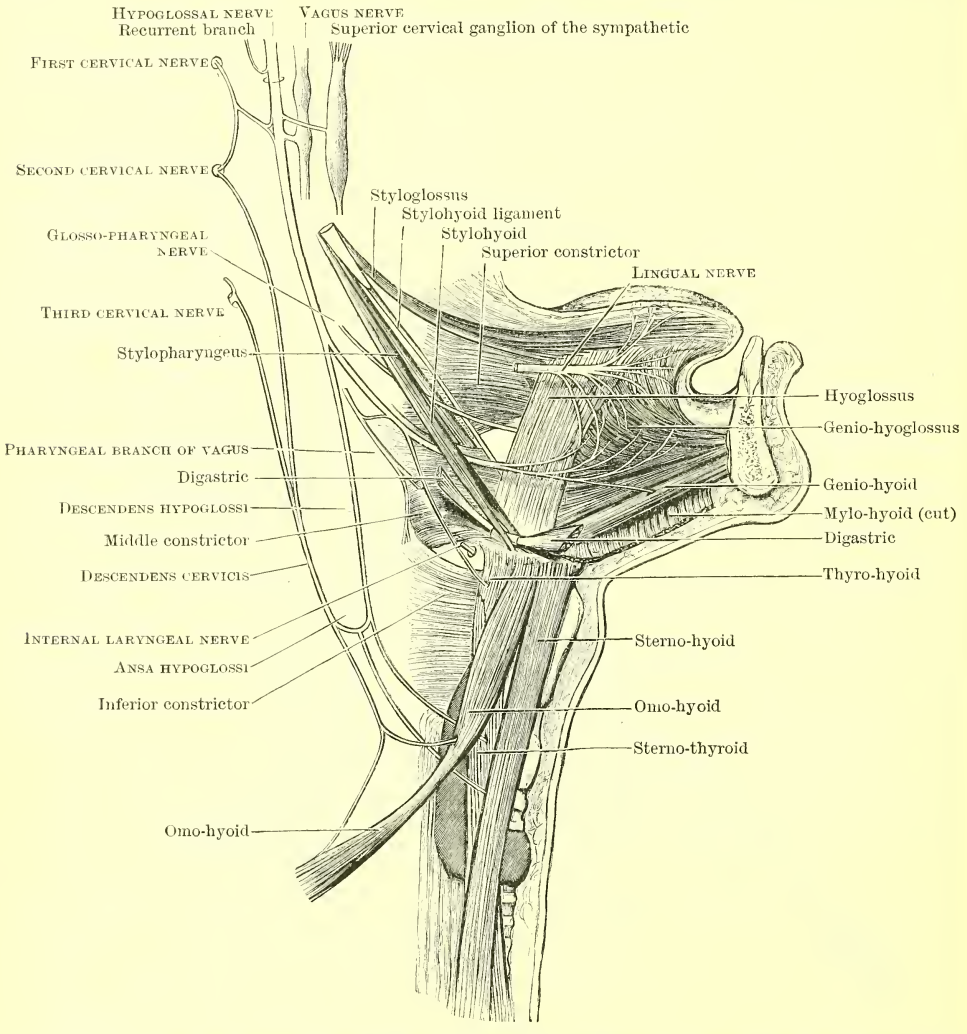


Fig. 493.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

join the spinal accessory nerve in three situations:—(*a*) A branch from the second cervical nerve to the sterno-mastoid joins the spinal accessory nerve *beneath that muscle.* (*b*) Branches to the trapezius from the third and fourth nerves are connected with the spinal accessory nerve *in the posterior triangle.* (*c*) Branches from the same nerves join the spinal accessory nerve *beneath the trapezius muscle.*

The **internal branches** of the plexus also comprise muscular and communicating branches. The first cervical nerve assists in the formation of this series of nerves, forming a slender loop with part of the second nerve in front of the transverse process of the atlas.

Communicating Branches. (*a*) *With the sympathetic.*—Gray rami communicantes pass to each of the first four cervical nerves, near their origins, from the

superior cervical ganglion or from the cord below the ganglion. (*b*) *With the pneumogastric nerve.*—The ganglion of the trunk of the pneumogastric nerve may be connected by a slender nerve with the loop between the first two cervical nerves. This communication is not constant. (*c*) *With the hypoglossal.*—An important communication occurs between the hypoglossal nerve and the loop between the first and second cervical nerves (Fig. 493). A trunk from the last-named nerves joins the hypoglossal just beyond its exit from the skull. One fine branch from this trunk passes upwards along the hypoglossal nerve towards the skull (*meningeal branch*). The main part of the trunk accompanies the hypoglossal and separates from it successively in three nerves—the **descendens hypoglossi**, and the **nerves to the thyro-hyoid** and **genio-hyoid muscles**. The portion of the nerve which remains accompanies the hypoglossal to the muscles of the tongue. It is probable that no part of the hypoglossal nerve itself is concerned in the formation of these three branches. The descending branch of the hypoglossal (r. descendens hypoglossi) descends in front of the common carotid artery, and is joined in the anterior triangle of the neck by the descending cervical nerve, to form the ansa hypoglossi, from which the infra-hyoid muscles are innervated. (The descending branch of the hypoglossal, in some cases, arises from the pneumogastric nerve.)

Muscular Branches.—The muscles supplied by the internal branches of the plexus are the prevertebral muscles, the genio-hyoid and infra-hyoid muscles, and the diaphragm.

(*a*) **Prevertebral Muscles.**—1. From the loop between the first and second cervical nerves a small branch arises, for the supply of the rectus capitis lateralis and the recti capitis antici (major and minor). 2. From the second, third, and fourth nerves small branches supply the inter-transversales, longus colli, and rectus capitis anticus major. 3. From the fourth nerve a branch arises for the upper part of the scalenus anticus.

(*b*) **Genio-hyoid and Infra-hyoid Muscles.**—The **descending cervical nerve** (n. cervicalis descendens) is formed in front of the internal jugular vein by the union of two slender trunks from the second and third cervical nerves. It forms a loop of communication in front of the carotid sheath with the descending branch of the hypoglossal nerve (derived ultimately from the first two cervical nerves). This loop of communication is called the **ansa hypoglossi**. It is often plexiform; and from it branches are given to the sterno-hyoid, sterno-thyroid, and omo-hyoid muscles. The nerve to the sterno-hyoid muscle is often continued behind the sternum, to join in the thorax with the phrenic nerve or the cardiac plexus.

The thyro-hyoid muscle and the genio-hyoid muscle are supplied by branches of the hypoglossal nerve, which are also traceable back to the communication between the hypoglossal and the first two cervical nerves.

The anterior muscles in immediate relation to the middle line of the neck, between the chin and the sternum, are thus continuously supplied by the first three cervical nerves. The hypoglossal is the nerve of the muscles of the tongue, and it is not certain that it contributes any fibres to the above-named muscles.

(*c*) **Diaphragm.**—The phrenic nerve supplies the diaphragm.

Phrenic Nerve.

The **phrenic nerve** (n. phrenicus) is derived mainly from the fourth cervical nerve, reinforced by roots from the third (either directly or through the nerve to the sterno-hyoid) and fifth (either directly or through the nerve to the subclavius muscle). It passes downwards in the neck upon the scalenus anticus muscle; at the root of the neck it enters the thorax between the subclavian artery and vein, and traverses the mediastinum to reach the diaphragm, lying in the middle mediastinum between the pericardium and pleura, and in front of the root of the lung. In its course it presents certain differences on the two sides. In the neck, on the left side, it crosses the first part of the subclavian artery: on the right side it crosses the second part. In the superior mediastinum, *on the left side*, it lies between the left subclavian and carotid arteries, and crosses the pneumogastric nerve and the aortic arch. *On the right side* it accompanies the innominate vein

and superior vena cava, and is entirely separate from the pneumogastric nerve. The left nerve is longer than the right, owing to the position of the heart and the left half of the diaphragm. The right nerve sends fibres along the inferior vena cava through the foramen quadratum. Reaching the diaphragm the nerve separates into numerous branches for the supply of the muscle; some enter its thoracic surface (sub-pleural branches), but most of the fibres supply it after piercing the muscle (sub-peritoneal branches).

The **branches of the phrenic nerve** are—1. Muscular (to the diaphragm); 2. pleural; 3. pericardiac; 4. inferior vena caval; 5. capsular; and 6. hepatic.

The branches to the pleura and pericardium arise as the phrenic nerve traverses the mediastinum. The branches to the inferior vena cava, suprarenal capsule, and liver arise after communication of the phrenic nerve with the diaphragmatic plexus of the sympathetic on the abdominal surface of the diaphragm.

Communications of the Phrenic Nerve.—1. The phrenic nerve may communicate with the nerve to the subclavius muscle. 2. It may communicate with the *ansa hypoglossi*, or a branch from it (the nerve to the sterno-hyoid). 3. It frequently communicates with the cervical part of the sympathetic. 4. It communicates with the solar plexus by a junction upon the abdominal surface of the diaphragm with the *diaphragmatic plexus* on the inferior phrenic artery, in which a small *diaphragmatic ganglion* is found on the right side. From this junction branches are given off to the inferior vena cava, suprarenal capsule, and hepatic plexus.

Morphology of the Cervical Plexus.

The characteristic feature of the cervical plexus is the combination of parts of adjacent nerves into compound nerve-trunks by the formation of series of loops. The result of the formation of these loops is that parts (particularly cutaneous areas) are supplied by branches of more than one spinal nerve.

A. **Cutaneous Distribution.**—By the combinations of the nerves into loops the discrimination of the elements in the upper cervical nerves, corresponding to the lateral and anterior branches of a typical thoracic nerve, is made a matter of some difficulty. The second, third, and fourth nerves, through the cervical plexus, supply an area of skin extending, laterally, from the side of the head to the shoulder; anteriorly, from the face to the level of the nipple. The higher nerves supply the upper region (second and third); the lower nerves supply the lower region (third and fourth). It is not possible to strictly compare the individual nerves with the lateral and anterior branches of a thoracic nerve. A line drawn from the ear to the middle of the clavicle separates, however, a lateral from an anterior cutaneous area; and certain of the cutaneous nerves fall naturally into one of these two categories. The nerves homologous with anterior branches of intercostal nerves are the superficial cervical and the sternal branches of the supra-clavicular series; those homologous with lateral branches are the small occipital and acromial branches. The great auricular and clavicular branches are mixed nerves, comprising elements belonging to both sets.

B. **Muscular Distribution.**—The nerves from the cervical plexus, supplying muscles, are simpler in their arrangement. They are not generally in the form of loops, and they are easily separated into lateral and anterior series. The lateral nerves comprise the branches to the rectus capitis lateralis, sterno-mastoid, trapezius, levator anguli scapulæ. The nerves in the anterior series are those to the recti antici, the hyoid muscles, and the diaphragm.

It is noteworthy that the last-named muscles—genio-hyoid, thyro-hyoid, sterno-hyoid, omo-hyoid, sterno-thyroid, and diaphragm—are continuously supplied by branches from the first five cervical nerves: the higher muscles by the higher nerves; the lower muscles by the lower nerves.

THE BRACHIAL PLEXUS.

The brachial plexus is formed by the anterior primary divisions of the fifth, sixth, seventh, and eighth cervical nerves, along with the greater part of the first thoracic nerve. In some cases a slender branch of the fourth cervical nerve is also engaged; and the second thoracic nerve, in all cases, also contributes to the innervation of the arm, through the intercosto-humeral nerve. It many cases it contributes also directly to the plexus, by an intra-thoracic communication with the first thoracic nerve.

Position of the Plexus—The nerves forming the brachial plexus appear in the posterior triangle of the neck between the scalenus anticus aud scalenus

medius muscles; the plexus is formed in close relation to the subclavian and axillary arteries; the nerves emanating from it accompany the artery to the axilla, where they are distributed to the shoulder and upper limb.

Communication with the Sympathetic.—The lower four cervical nerves communicate with the cervical portion of the sympathetic by means of **gray rami communicantes.** Two branches arise from the middle cervical ganglion, and join the anterior primary divisions of the fifth and sixth nerves. Two arising from the inferior cervical ganglion join the seventh and eighth nerves. They reach the nerves either by piercing the prevertebral muscles or by passing round the border of the scalenus anticus muscle.

Composition of the Brachial Plexus.—In an analysis of the brachial plexus four stages may be always seen:—

(1) The undivided nerves.

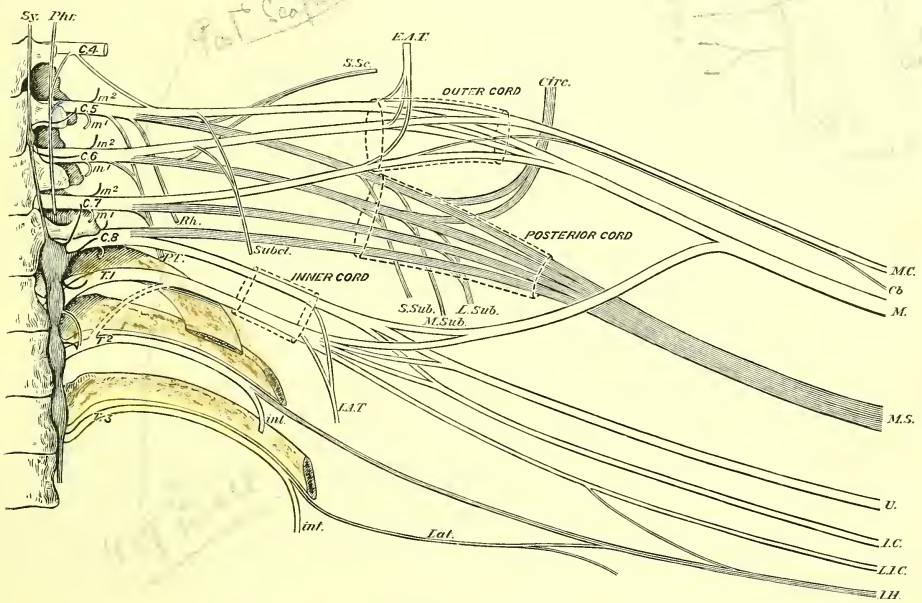


Fig. 494.—The Nerves of the Brachial Plexus.

Sy, Sympathetic gangliated cord; Phr, Phrenic nerve; C.4, 5, 6, 7, 8, T.1, 2, 3, Anterior primary divisions of the lower cervical and upper thoracic nerves; M^1, M^2, Muscular branches to axial muscles; P.T, Long thoracic nerve; Rh, Nerve to rhomboids (posterior scapular); Subcl, Nerve to subclavius muscle; Int, Intercostal nerves; S.Sc, Supra-scapular nerve. The intercostal part of the first thoracic nerve is omitted.

Outer Cord.—E.A.T, External anterior thoracic nerve; M.C, Musculo-cutaneous nerve; Cb, Nerve to coraco-brachialis; M, Median nerve.

Inner Cord.—I.A.T, Internal anterior thoracic nerve; U, Ulnar nerve; I.C, Internal cutaneous nerve; L.I.C, Lesser internal cutaneous nerve.

Posterior Cord.—Circ, Circumflex nerve; M.S, Musculo-spiral nerve; S.Sub, Short subscapular nerve; M.Sub, Lower subscapular nerve; L.Sub, Long subscapular, nerve; I.H, Intercosto-humeral nerve; Lat, Lateral branch of third intercostal nerve.

(2) The separation of the nerves into ventral (anterior) and dorsal (posterior) trunks; and the formation of three primary cords.

(3) The formation of three secondary cords—outer, inner, and posterior.

(4) The origin of the nerves of distribution.

(1) The undivided nerves have only a very short independent course at the side of the neck, after passing between the scalene muscles.

(2) Almost immediately after entering the posterior triangle there are formed three **primary cords**: the first cord is formed by the union of the fifth and sixth nerves together; the second, by the seventh nerve alone; and the third, by the union of the eighth cervical and first thoracic nerves together. While these cords are being formed, a division occurs in each of the last four cervical nerves, into *ventral* (anterior) and *dorsal* (posterior) *trunks*; the first thoracic nerve usually gives rise to no dorsal trunk. The ventral and dorsal trunks of the fifth, sixth,

and seventh nerves are nearly equal in size. The dorsal trunk of the eighth cervical nerve is much smaller.

(3) The **secondary cords** of the plexus are formed by combinations of these ventral and dorsal trunks in relation to the axillary artery. They are three in number. The **outer cord** (fasciculus lateralis) is formed by a combination of the ventral trunks of the fifth, sixth, and seventh nerves, and lies on the outer side of the axillary artery. The **inner cord** (fasciculus medialis) is formed by a combination of the ventral trunk of the eighth cervical with the part of the first thoracic nerve engaged in the formation of the plexus; it lies on the inner side of the axillary artery. The **posterior cord** (fasciculus posterior) is made up of all the dorsal trunks from the fifth, sixth, seventh, and eighth cervical nerves, and lies behind the axillary artery. The first thoracic nerve does not usually contribute to the posterior cord, and the branch when present is a fine nerve.

(4) The **nerves of distribution** for the shoulder and arm are derived from these secondary cords, and receive in this way various contributions from the constituent spinal nerves. *From the outer cord* arise the external anterior thoracic and musculo-cutaneous nerves, and the outer head of the median nerve. *From the inner cord* arise the inner head of the median, the ulnar, internal cutaneous, lesser internal cutaneous, and the internal anterior thoracic nerves. *From the posterior cord* arise the circumflex, the three subscapular, and the musculo-spiral nerves.

It is to be remembered that, although derived from a secondary cord formed by a certain set of spinal nerves, any given nerve does not necessarily contain fibres from all the constituent nerves; *e.g.* both the musculo-cutaneous and circumflex nerves, from the outer and posterior cords respectively, are ultimately derived only from the fifth and sixth cervical nerves.

The Branches of the Brachial Plexus.

It is customary to separate artificially the nerves of distribution of the brachial plexus into two sets: (1) supra-clavicular and (2) infra-clavicular. Clinically it is important to realise the position of origin of certain nerves. The nerves to the prevertebral muscles, the communication with the phrenic, the posterior scapular, and long thoracic nerves, arise from the *roots* of the nerves involved in the plexus. The supra-scapular and the nerve to the subclavius arise at the level of formation of the secondary cords; and the anterior thoracic and subscapular nerves arise from the secondary cords, prior to their ultimate subdivision into the nerves of distribution for the upper limb.

Supra-clavicular Nerves.—The nerves derived from the plexus above the level of the clavicle are, like the main trunks, divisible into two series; **anterior branches** arising from the front, and **posterior branches** arising from the back of the plexus (Fig. 494, p. 623).

Anterior Branches.	Posterior Branches.
1. Nerves to scalenus anticus and longus colli.	1. Nerves to scaleni, medius and posticus.
2. Communicating nerve to join the phrenic nerve.	2. Posterior scapular nerve.
3. Nerve to the subclavius muscle.	3. Long thoracic nerve.
	4. Supra-scapular nerve.

The **muscular twigs** to the scalenus anticus and longus colli arise from the lower four cervical nerves, as they emerge from the intervertebral foramina.

The **communicating nerve to the phrenic** arises usually from the fifth cervical nerve at the outer border of the scalenus anticus. It is sometimes absent, and occasionally an additional root is present from the sixth cervical nerve. In some instances the nerve is replaced by a branch from the nerve to the subclavius, which passes inwards behind the sterno-mastoid muscle to join the phrenic at the inlet of the thorax.

The **nerve to the subclavius** is a slender nerve, which arises from the front of the cord formed by the fifth and sixth cervical nerves. It descends in the posterior triangle of the neck over the third part of the subclavian artery. It often communicates with the phrenic nerve.

The **branches to the scaleni, medius and posticus,** are small trunks which arise from the lower four cervical nerves as they emerge from the intervertebral foramina.

The **posterior scapular nerve** (n. dorsalis scapulæ, nerve to the rhomboids) arises from the back of the fifth cervical nerve, as it emerges from the intervertebral foramen. It appears in the posterior triangle of the neck, after piercing the scalenus medius muscle. It is directed downwards, under cover of the levator anguli scapulæ and rhomboid muscles, and along the vertebral border of the scapula, to be distributed to the levator anguli scapulæ, rhomboideus minor, and rhomboideus major muscles. It occasionally pierces the levator anguli scapulæ.

The **long thoracic nerve** (n. thoracalis longus, external respiratory nerve of Bell) arises by three roots, of which the middle one is usually the largest, from the back of the fifth, sixth, and seventh nerves, as they emerge from the intervertebral foramina. The nerve pierces the scalenus medius as two trunks, of which the lower represents the contribution from the seventh cervical nerve, and, descending along the side of the neck behind the cords of the brachial plexus, it enters the axilla between the upper edge of the serratus magnus and the axillary artery. It continues its downward course over the outer surface of the serratus magnus, to which it is distributed.

There is a more or less definite relation between the roots of this nerve and the parts of the serratus magnus. The first part of the muscle is innervated by the fifth nerve alone; the second part by the fifth and sixth, or the sixth alone; the third part by the sixth and seventh, or the seventh nerve alone.

The **suprascapular nerve** (n. suprascapularis) arises from the back of the cord formed by the fifth and sixth cervical nerves in the posterior triangle of the neck. It occupies a position above the main cords of the brachial plexus, and courses downwards and outwards parallel to them towards the superior border of the scapula. It passes through the suprascapular foramen to reach the dorsum of the scapula. After supplying the supraspinatus muscle it winds round the great scapular notch in company with the suprascapular artery and terminates in the infraspinatus muscle. It also supplies articular branches to the back of the shoulder joint.

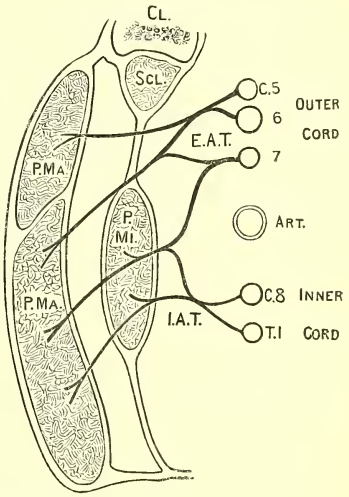


FIG. 495.—DIAGRAM OF THE ORIGIN AND DISTRIBUTION OF THE NERVES TO THE PECTORAL MUSCLES.

E.A.T, External anterior thoracic nerve; I.A.T, Internal anterior thoracic nerve; C.5, 6, 7, C.8, T.1, Nerves of the brachial plexus; ART, Axillary artery; CL, Clavicle; SCL, Subclavius muscle; P.MI, Pectoralis minor, joined to subclavius by costo-coracoid membrane; P.MA, Pectoralis major.

Infra-clavicular Nerves.—The so-called infra-clavicular branches of the brachial plexus are distributed to the chest, shoulder, and arm. According to their origin they are divisible into two sets—an **anterior set,** derived from the outer and inner cords, and a **posterior set,** derived from the posterior cord. In their distribution the same division is maintained. The anterior nerves of distribution, springing from the outer and inner cords, supply generally the chest and the front of the limb; the posterior nerves, springing from the posterior cord, supply the shoulder and the back of the limb.

Anterior Branches.

Nerves from the Outer Cord.

External anterior thoracic. Outer head of median. Musculo-cutaneous.

Nerves from the Inner Cord.

Internal anterior thoracic. Ulnar. Inner head of median.
Internal cutaneous. Lesser internal cutaneous.

Posterior Branches.

Nerves from the Posterior Cord.

Circumflex. Musculo-spiral. Three subscapular nerves.

Anterior Thoracic Nerves.

The **anterior thoracic nerves** (nn. thoracicales anteriores) are two in number, external and internal. The **external anterior thoracic nerve** arises from the outer

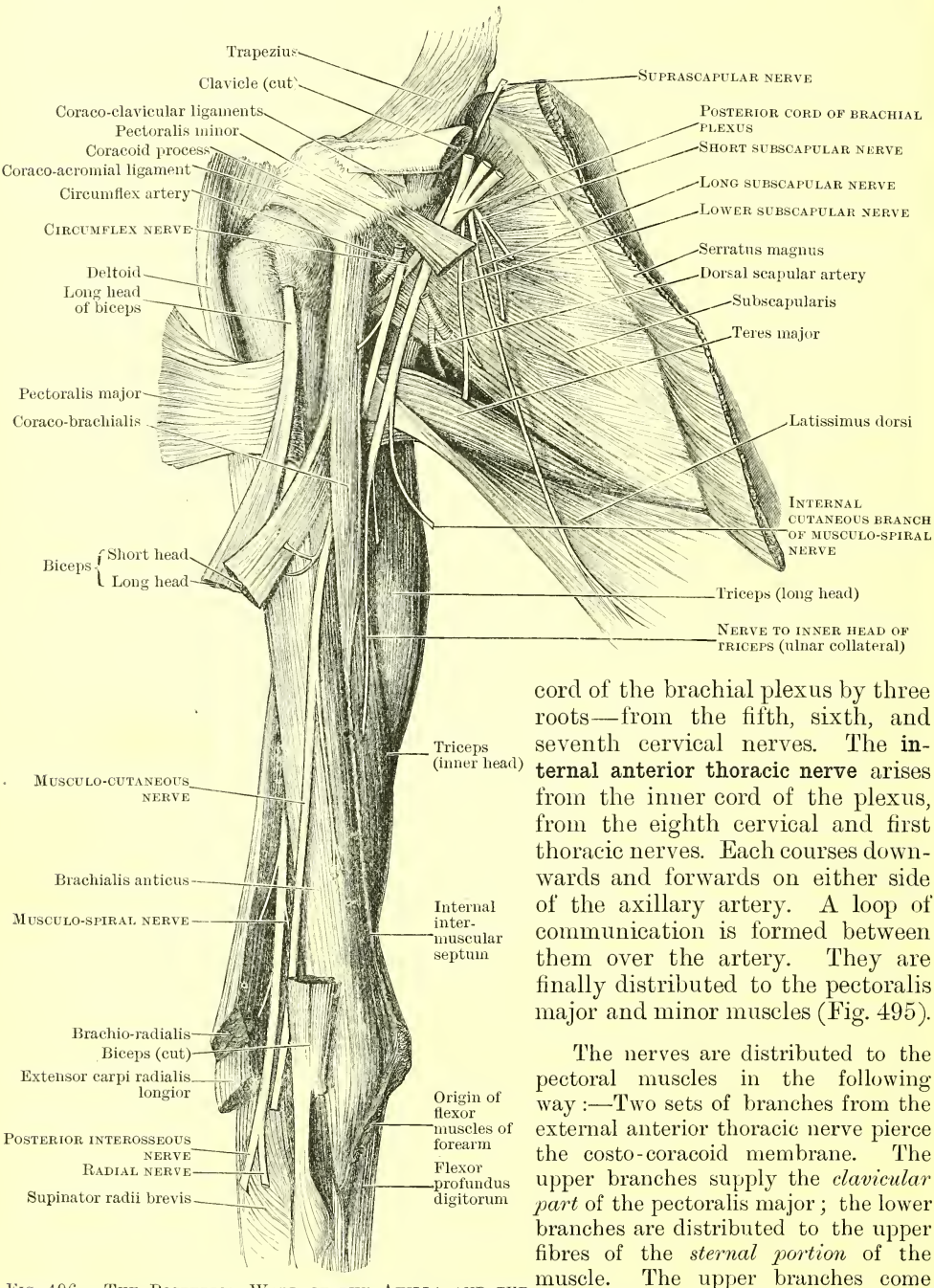


Fig. 496.—The Posterior Wall of the Axilla and the Front of the Arm (the biceps being divided).

cord of the brachial plexus by three roots—from the fifth, sixth, and seventh cervical nerves. The **internal anterior thoracic nerve** arises from the inner cord of the plexus, from the eighth cervical and first thoracic nerves. Each courses downwards and forwards on either side of the axillary artery. A loop of communication is formed between them over the artery. They are finally distributed to the pectoralis major and minor muscles (Fig. 495).

The nerves are distributed to the pectoral muscles in the following way:—Two sets of branches from the external anterior thoracic nerve pierce the costo-coracoid membrane. The upper branches supply the *clavicular part* of the pectoralis major; the lower branches are distributed to the upper fibres of the *sternal portion* of the muscle. The upper branches come from the fifth and sixth cervical nerves; the lower branches, from the fifth, sixth, and seventh nerves. The *pectoralis minor* is pierced by two sets of nerves—the upper set is derived from the loop of communication between the external and internal anterior thoracic nerves over the axillary artery; the lower set is derived from the internal anterior thoracic nerve alone. These nerves supply the *pectoralis minor* muscle, and, after piercing it, supply the *sternal part* of the pectoralis major. The lower nerve, in

many cases, sends its branches to the pectoralis major round the lower border of the pectoralis minor, and it may supply on its way the *axillary arches*, if present. These two branches are derived—the upper from the seventh, eighth cervical, and first thoracic nerves; the lower from the eighth cervical and first thoracic nerves. The pectoral muscles are thus both supplied by the two anterior thoracic nerves. The clavicular fibres of the pectoralis major are innervated by the fifth and sixth nerves; the sternal fibres, from above downwards, by the fifth, sixth, seventh, and eighth cervical, and first thoracic nerves; and the pectoralis minor is supplied by the seventh and eighth cervical, and first thoracic nerves.

Musculo-Cutaneous Nerve.

The **musculo-cutaneous nerve** (n. musculo-cutaneus) takes origin from the outer cord of the plexus, from the fifth and sixth cervical nerves (Fig. 496). The **nerve to the coraco-brachialis muscle,** arising from the seventh or sixth and seventh nerves, is usually associated with it. Separating from the outer head of the median nerve, the musculo-cutaneous nerve lies at first between the coraco-brachialis muscle and the axillary artery. It is then directed downwards between the two parts of the coraco-brachialis, and passes between the biceps and brachialis anticus muscles, to the bend of the elbow. In its course it may send a branch under the biceps to join the median nerve. It pierces the deep fascia over the front of the elbow, between the biceps and brachio-radialis, and terminates in cutaneous branches for the supply of the outer side of the forearm.

The branches of the nerve are muscular and cutaneous. The **muscular branches** are supplied to the two heads of the biceps and the brachialis anticus, as the nerve lies between the muscles. The nerve to the coraco-brachialis (usually incorporated with the trunk of the musculo-cutaneous nerve) has an independent origin from the seventh or sixth and seventh nerves. It is usually double, one branch entering each portion of the muscle. The **cutaneous branches** are anterior and posterior (Fig. 497, p. 628). The **anterior branch** descends along the front of the outer side of the forearm to the wrist, and supplies an area extending inwards to the middle line of the forearm anteriorly, and downwards so as to include the ball of the thumb. It communicates above the wrist with the radial nerve, and supplies branches to the radial artery. The **posterior** branch passes backwards and downwards over the extensor muscles and supplies the skin on the outer aspect of the forearm posteriorly in its upper three-fourths, communicating with the cutaneous branches of the musculo-spiral nerve.

In addition to the above branches, the musculo-cutaneous nerve supplies in many cases the following small twigs in the arm: (1) a medullary branch to the humerus; (2) a periosteal branch to the lower end of the humerus on its anterior surface; and (3) a branch to the brachial artery.

Median Nerve.

The **median nerve** (n. medianus) arises by two roots—one from the outer cord, the other from the inner cord of the brachial plexus. The outer head, from the (fifth), sixth, and seventh nerves, descends along the outer side of the axillary artery; the inner head, from the eighth cervical and first thoracic nerves, crosses the end of the axillary artery or the beginning of the brachial artery, to join the other head in the upper part of the arm. Descending along the outer side of the brachial artery, the nerve crosses over it obliquely in the lower half of the arm. In the hollow of the elbow, it lies internal to the brachial artery, beneath the bicipital fascia and the median basilic vein. It passes into the forearm between the two heads of the pronator radii teres muscle, separated from the ulnar artery by the deep origin of that muscle. Extending down the middle of the forearm, between the superficial and deep muscles to the wrist, it enters the palm of the hand on the outer side of the flexor tendons of the fingers beneath the anterior annular ligament. In the hand it spreads out at the lower border of the annular ligament beneath the palmar fascia and superficial palmar arch, and separates into its six terminal branches. In the forearm a small artery accompanies it,—the comes nervi mediani. Above the wrist it is comparatively superficial, lying on the outer side of the superficial flexor tendons and directly beneath the tendon of the palmaris longus.

Communications.—(1) The median, in some cases, receives a communicating branch from the musculo-cutaneous nerve in the arm. (2) It communicates in some cases, in the upper part of the forearm, with the ulnar nerve beneath the flexor muscles. (3) It communicates by means of its cutaneous branches with the ulnar nerve in the palm of the hand.

Branches.—The median nerve usually gives off no branches in the upper arm.

Branches in the Forearm.—(1) **Articular Branches.**—Minute articular filaments are distributed to the front of the elbow-joint.

(2) **Muscular Branches.**—Just below the elbow a bundle of nerves arise which is distributed to the following muscles: pronator radii teres, flexor carpi radialis, palmaris longus, flexor sublimis digitorum. Nerves are also generally traceable from this bundle to the upper fibres of the flexor longus pollicis and flexor profundus digitorum. The nerve to the pronator radii teres often arises independently in the hollow of the elbow.

(3) The **anterior interosseous nerve** arises from the back of the median nerve in the forearm, descends in front of the interosseous membrane along with the anterior interosseous artery, passes behind the pronator quadratus muscle, and terminates by supplying articular filaments to the radiocarpal articulation. In its course the nerve supplies muscular branches to the flexor longus pollicis, the outer half of the flexor profundus digitorum, and the pronator quadratus, minute medullary branches to the radius and ulna, and twigs to the periosteum and interosseous membrane.

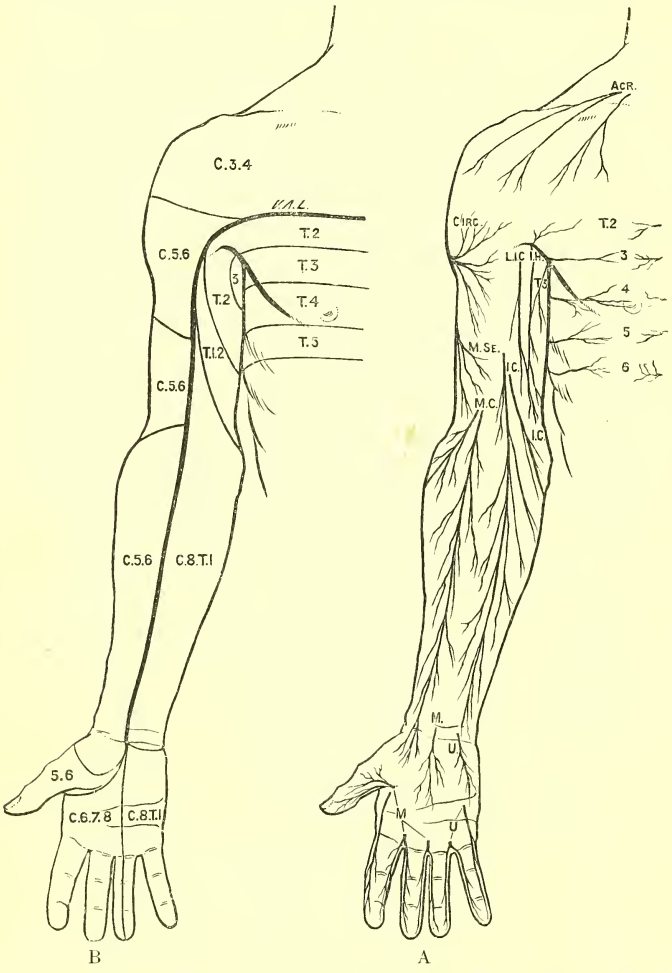


FIG. 497.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE ARM AND HAND.

(A) represents the distribution of the several nerves, the letters indicating their nomenclature. ACR, Acromial branch (cervical plexus); CIRC, Cutaneous branch of circumflex nerve; M.SE, Superior external cutaneous branch of musculo-spiral nerve; M.C, Musculo-cutaneous nerve; M, Median nerve; U, Ulnar nerve; I.C, Internal cutaneous nerve; L.I.C, Lesser internal cutaneous nerve (Wrisberg); I.H, Intercosto-humeral nerve; T.2, 3, 4, 5, 6, Anterior and lateral branches of intercostal nerves.

(B) is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. V.A.L, Ventral axial line.

(4) **Palmar Cutaneous Branch.**—In the lower third of the forearm a small cutaneous branch arises, which pierces the deep fascia and crosses the anterior annular ligament to reach the palm of the hand. It supplies the skin of the palm and communicates with a similar branch of the ulnar nerve. This branch is not always present.

Branches in the Hand.—In the hand the median nerve gives off its terminal branches. These are muscular and cutaneous.

The main **muscular branch** arises just below the anterior annular ligament and passes outwards to the base of the thenar eminence; entering the ball of the thumb superficially on the inner side, it supplies branches to the abductor pollicis, opponens pollicis, and the superficial head of the flexor brevis pollicis.

The **cutaneous branches** are five in number. Three separate branches supply each side of the thumb and the radial side of the index finger. The two remaining branches subdivide at the cleft between the second and third, and the third and fourth fingers respectively, into branches which supply the adjacent sides of the second and third, and the third and fourth fingers. From the nerves which supply respectively the radial side of the index finger, and the contiguous sides of the index and third fingers, fine muscular branches arise for the two outer lumbrical muscles. The cutaneous branches of the median nerve are placed in the palm between the superficial palmar arch and the flexor tendons. They become superficial at the roots of the fingers between the slips of the palmar fascia, or, in the case of the nerves to the thumb and radial side of the index finger, at the outer edge of the central portion of the palmar fascia. In the fingers they are placed superficial to the digital arteries, and are distributed to the sides and front of the fingers. Each nerve supplies one or more dorsal branches, distributed to the skin on the dorsal aspect of the terminal phalanx of the thumb and the two distal phalanges of the first two and a half fingers, thus making up for the deficiency of the radial nerve in these situations.

Ulnar Nerve.

The **ulnar nerve** (n. ulnaris) arises from the inner cord of the brachial plexus, from the eighth cervical and first thoracic nerves. It also occasionally has a root from the outer cord of the plexus (seventh cervical nerve). In the axilla it lies between the axillary artery and vein, and behind the internal cutaneous nerve; in the upper half of the upper arm it lies on the inner side of the brachial artery in front of the triceps muscle. In the lower half of the arm it is separated from the brachial artery; and passing behind the intermuscular septum, and in front of the inner head of the triceps in company with the inferior profunda artery, it reaches the interval between the internal condyle of the humerus and the olecranon process. It is here protected by an arch of deep fascia stretching between the internal condyle and the olecranon process. It enters the forearm between the humeral and ulnar origins of the flexor carpi ulnaris, and courses downwards between the flexor carpi ulnaris and flexor profundus digitorum. In the lower half of the forearm it becomes comparatively superficial, lying on the inner side of the ulnar artery beneath the tendon of the flexor carpi ulnaris. Just above the anterior annular ligament of the wrist, and external to the pisiform bone, it pierces the deep fascia in company with the artery and passes into the hand over the anterior annular ligament. Reaching the palm it divides beneath the palmaris brevis muscle into its two terminal branches, superficial and deep.

Communications.—(1) The ulnar nerve communicates in some cases with the median nerve in the forearm; (2) with the internal cutaneous and sometimes the median nerve by its palmar cutaneous branch; (3) with the cutaneous part of the median nerve in the palm by means of its terminal cutaneous branches; (4) with the radial nerve on the dorsum of the hand by means of its dorsal branch.

Branches.—The ulnar nerve gives off no branches till it reaches the forearm.

In the forearm it gives off articular, muscular, and cutaneous branches.

The **articular branch** is distributed to the elbow joint and arises as the nerve passes behind the internal condyle.

The **muscular branches** arise as soon as the nerve enters the forearm. They are distributed to the muscles between which the ulnar nerve lies—the flexor carpi ulnaris and the inner half of the flexor profundus digitorum.

The **cutaneous branches** are two in number, palmar and dorsal.

The **palmar cutaneous branch** is variable in size and position. It pierces the deep fascia in the lower third of the forearm and passes to the hypothenar eminence and palm of the hand, to the skin over which it is distributed. It gives branches to the ulnar artery, and communicates often with the internal cutaneous and palmar branch of the median nerve.

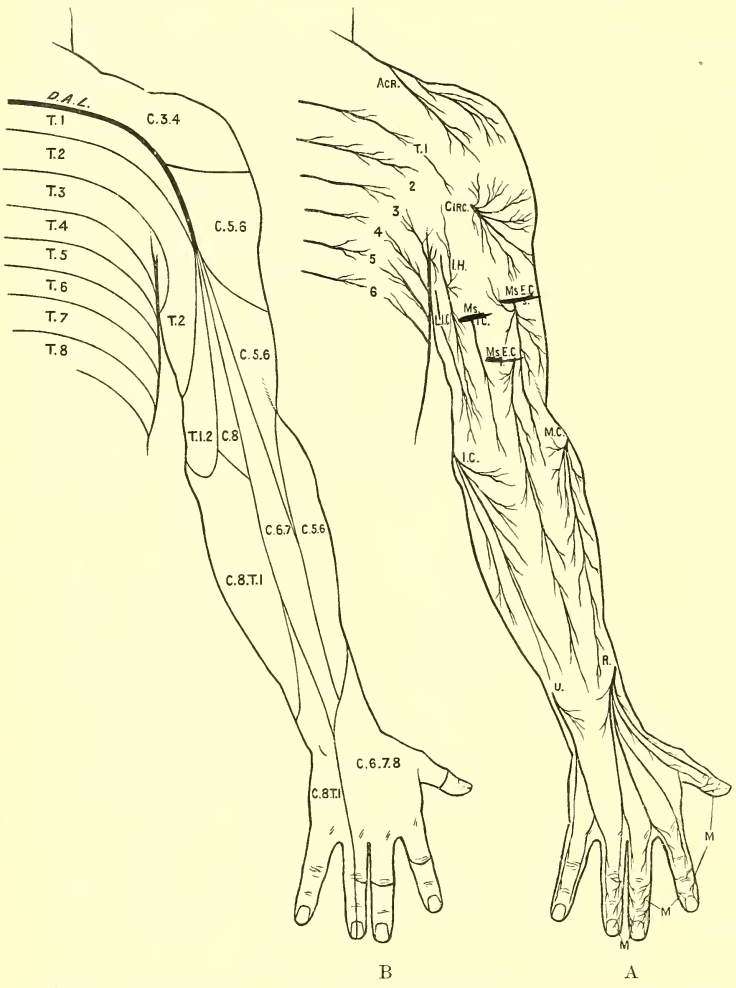


Fig. 498.—The Distribution of Cutaneous Nerves on the Back of the Arm and Hand.

(A) represents the distribution of the several nerves, the letters indicating their nomenclature. Acr, Acromial branches (cervical plexus); Circ, Cutaneous branch of circumflex nerve; Ms.E.C.s, Ms.E.C.i, Superior and inferior external cutaneous branches of musculo-spiral nerve; M.C, Musculo-cutaneous nerve: R, Radial nerve; M, Branches of median nerve to fingers; U, Ulnar nerve; I.C, Internal cutaneous nerve; Ms.I.C, Internal cutaneous branch of musculo-spiral nerve; L.I.C, Lesser internal cutaneous nerve (Wrisberg); I.H, Intercosto-humeral; T.1, 2, 3, 4, 5, 6, Lateral and posterior branches of upper thoracic nerves.

(B) is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. D.A.L, Dorsal axial line.

The **dorsal cutaneous branch** is much larger (Fig. 498). It arises from the ulnar nerve in the middle third of the forearm; and, directed obliquely downwards and backwards beneath the tendon of the flexor carpi ulnaris, it becomes cutaneous on the inner side of the forearm in its lower fourth. It passes on to the back of the hand, and after giving off branches to the skin of the wrist and hand, which communicate with the radial nerve, it terminates in two branches, to supply the little finger and half the ring-finger in the following way:—the inner branch courses along the inner side of the dorsum of the hand and little finger: the outer branch subdivides at the cleft between the ring and little fingers to supply the adjacent sides of these fingers; this branch communicates with the radial nerve. The nerve may supply two and a half fingers on the dorsum of the hand.

In the palm the ulnar nerve supplies a small muscular branch to the palmaris brevis muscle, and then subdivides into its terminal branches, which are named superficial and deep.

The **superficial branch** is purely cutaneous; it passes downwards beneath the palmar fascia, and subdivides into an inner and an outer branch. The inner branch courses along the inner border of the little finger, which it supplies on its

palmar aspect. The outer branch becomes superficial at the cleft between the fourth and fifth fingers, between the slips of the palmar fascia, and subdivides into two branches which supply the adjacent sides of these fingers on their palmar aspect. It communicates with the adjacent digital branch of the median nerve.

The **deep branch** is purely muscular. It separates from the superficial branch, and passes deeply between the flexor brevis and abductor minimi digiti muscles; it supplies these muscles and the opponens minimi digiti, and, turning outwards along the line of the deep palmar arch and under cover of the deep flexor tendons, it supplies branches to the following muscles: interossei, two inner (third and fourth) lumbricales (on their deep surfaces), the adductores pollicis, obliquus and transversus, and deep part of the flexor brevis pollicis.

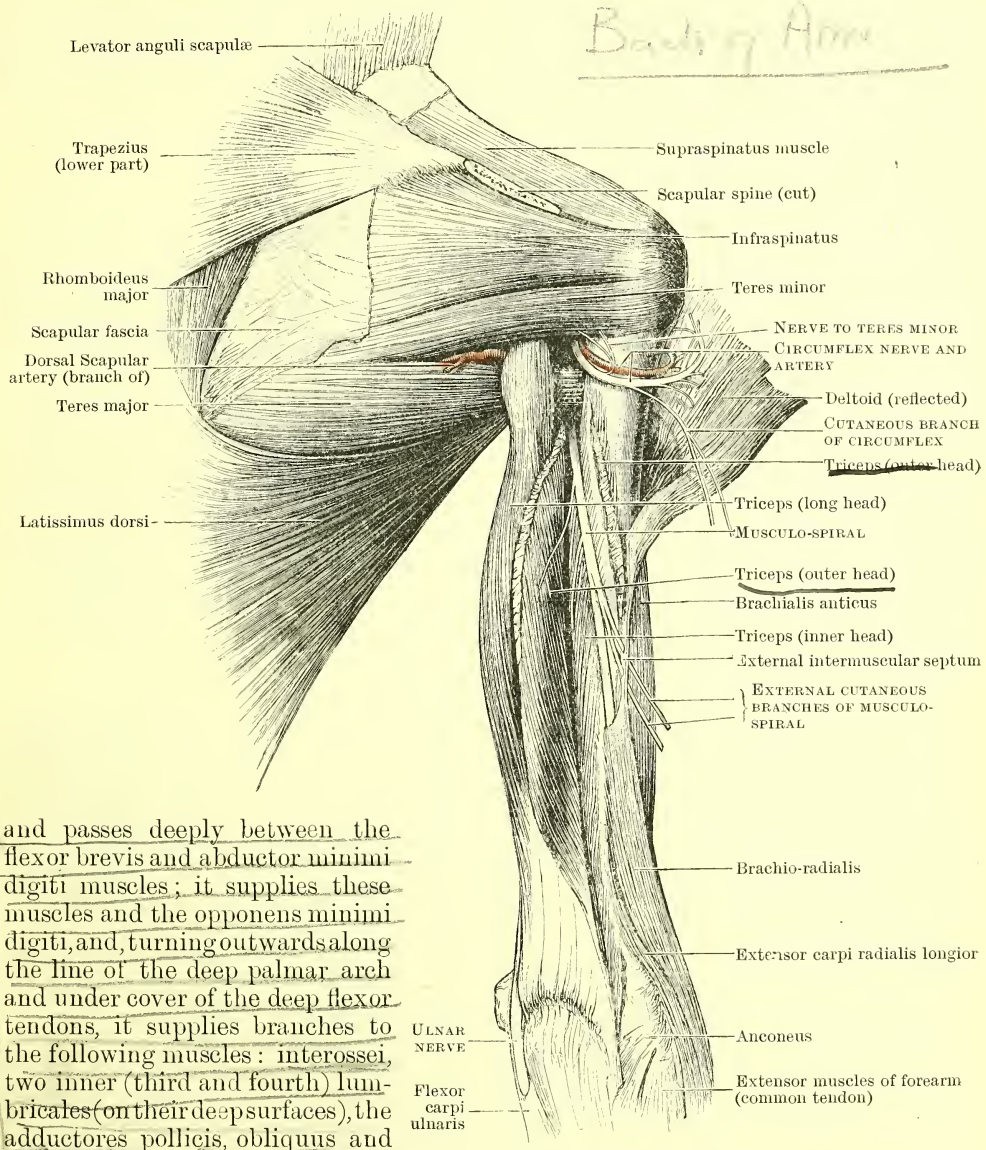


Fig. 499. - Deltoid Region and Back of Arm.

Internal Cutaneous Nerve.

The **internal cutaneous nerve** (n. cutaneus brachii medialis) arises from the inner cord of the brachial plexus, from the eighth cervical and first thoracic nerves (Figs. 497 and 498). In the axilla and upper half of the arm it lies superficial to the main artery. It becomes cutaneous by piercing the deep fascia about the middle of the inner side of the upper arm, and accompanying the basilic vein through the lower half of the arm, it divides at the front of the elbow into its two terminal branches.

Communication.—The internal cutaneous nerve communicates with the palmar branch of the ulnar nerve in the lower part of the forearm.

Branches.—In the arm, as soon as it becomes superficial, the internal cutaneous nerve gives off a branch which supplies the skin of the lower half of the anterior surface of the arm on its inner side. At the elbow it divides into two terminal branches—anterior and internal, which, crossing over or under the median basilic vein, are distributed to the inner side of the forearm.

The **anterior branch** can be followed to the wrist and supplies the whole of the front of the forearm in the inner half; the **internal branch** is not so large, and, passing obliquely backwards and downwards over the origins of the pronator and flexor muscles, it is distributed to the upper two-thirds or three-fourths of the posterior aspect of the forearm on the inner side.

Lesser Internal Cutaneous Nerve.

The **lesser internal cutaneous nerve** (n. cutaneus brachii medialis minor) arises from the inner cord of the brachial plexus, and ultimately from the first thoracic nerve (Fig. 494, p. 624). It lies at first between the axillary artery and vein; and after descending over, under, or even, in some cases, through the axillary vein, it perforates the deep fascia on the inner side of the arm, and is distributed to the skin of the arm for the upper half or more on its inner side.

The nerve varies considerably in size. It may be absent, its place being taken by branches of the intercosto-humeral or by branches from the internal cutaneous offset of the musculo-spiral nerve. It generally bears a distinct relation in size to the intercosto-humeral, due to the fact that the size of the latter depends upon the size of the part of the second thoracic nerve connected with the first in the thorax. If an intra-thoracic connexion occurs between the first and second thoracic nerves, the intercosto-humeral may be deprived of a certain number of its fibres, which in that case reach the upper limb through the lesser internal cutaneous nerve. When traced up to the plexus the lesser internal cutaneous is found to have an origin from the back of the cord formed by the eighth cervical and first thoracic nerves, and usually receives fibres from the first thoracic nerve only. In cases where "*axillary arches*" are present they may be supplied by this nerve.

Circumflex Nerve.

The **circumflex nerve** (n. axillaris), at its origin is just below the supra-scapular and comes from the same spinal nerves—the fifth and sixth cervical nerves (Fig. 494, p. 623). Extending downwards and outwards behind the axillary artery, it leaves the axilla by passing round the external border of the subscapularis muscle, in company with the posterior circumflex artery, in a quadrilateral space bounded by the humerus, subscapularis, triceps (long head), and teres major. Winding round the surgical neck of the humerus from within outwards, it terminates under the deltoid by supplying that muscle (Fig. 499, p. 631).

Branches.—**Muscular branches** are supplied to the teres minor and deltoid muscles. The nerve to the teres minor enters the outer side of the muscle. It possesses a pseudo-ganglion, a thickening of fibrous tissue, on its trunk.

Articular branches enter the back part of the capsule of the shoulder-joint.

A **cutaneous branch** (n. cutaneus brachii lateralis) of considerable size passes obliquely downwards and forwards from beneath the deltoid muscle, becoming superficial at its posterior border. Sometimes the branches pierce the muscle. It supplies the skin over the insertion of the deltoid and the upper half of the arm on the outer side (Fig. 498, p. 630).

Musculo-Spiral Nerve.

The **musculo-spiral** nerve (n. radialis) appears to be the continuation into the upper limb of the posterior cord of the brachial plexus. It usually takes origin from all the nerves which form the posterior cord—the fifth, sixth, seventh, and eighth cervical nerves (Fig. 494, p. 623). In a minority of cases the first thoracic contributes a few fibres, and more frequently the fifth cervical nerve is excluded from it. It extends from the axilla round the back of the humerus to the bend of the elbow, where it ends by dividing into its terminal branches.

In the axilla it lies behind the axillary artery, and in front of the subscapularis, teres major, and latissimus dorsi muscles.

In the arm, in the upper third, it lies on the inner side of the humerus behind the brachial artery, and upon the long head of the triceps. In the middle third of the arm it courses obliquely outwards and downwards in the spiral groove of the humerus, along with the superior profunda artery, separating the long, external, and internal heads of the triceps muscle (Fig. 499, p. 631). In the lower third of the arm, piercing the upper part of the intermuscular septum at the outer border of the triceps muscle, it descends to the bend of the elbow in front of the external condyle of the humerus, in the interval between the brachio-radialis and brachialis anticus muscles. Under cover of the former muscle, in the hollow of the elbow, it divides into its two terminal branches, the radial and posterior interosseous nerves.

The **collateral branches** are in three sets, arising (*a*) on the inner side, (*b*) on the back, and (*c*) on the outer side of the humerus (Fig. 500).

Branches arising internal to the humerus.—1. **Internal cutaneous** (n. cutaneus brachii posterior).—This branch, arising in common with one of the following, or independently, pierces the fascia on the inner side of the arm near the axilla. It supplies the skin of the inner side of the arm in the upper third, above and behind the area supplied by the lesser internal cutaneous nerve (Fig. 498, p. 630). This nerve varies in size, according to the bulk of the lesser internal cutaneous and intercosto-humeral nerves.

2. **Muscular branches** (rr. musculares).—These are in two sets. One series supplies the long head of the triceps muscle near its origin; the other series enters the inner head of the muscle. One of the latter, separating itself from the rest, accompanies the ulnar nerve in the middle third of the arm, and supplies the lower part of the muscle. This is sometimes called the **collateral ulnar nerve.**

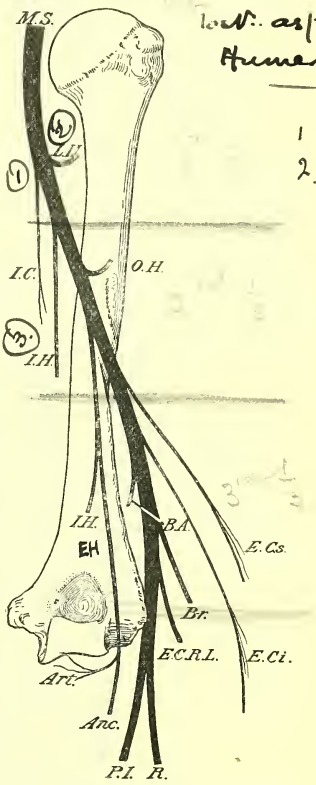


FIG. 500.—DIAGRAMMATIC REPRESENTATION OF THE BRANCHES OF THE MUSCULO-SPIRAL NERVE.

M.S, Musculo-spiral nerve; L.H, Nerve to long head of triceps; I.C, Internal cutaneous branch; I.H, Nerve to inner head of triceps; O.H, Nerve to outer head of triceps; I.H, Second nerve to inner head of triceps; Anc. Nerve to anconeus; Art, Articular branch; E.Cs, Superior, external cutaneous branch; E.Ci, Inferior external cutaneous branch; B.A, Nerve to brachialis anticus; Br, Nerve to brachio-radialis; E.C.R.L, Nerve to extensor carpi radialis longior; P.I, Posterior interosseous nerve; R, Radial nerve.

Branches arising on the back of the humerus.—**Muscular branches** arise from the nerve in the musculo-spiral groove for the supply of all three heads of the triceps muscle. The branch which enters the inner head of the muscle, besides supplying it, passes through the muscle and behind the external condyle of the humerus, to terminate in the anconeus.

Branches arising at the outer side of the humerus.—1. The **cutaneous branches** (n. cutaneus antibrachii dorsalis) are two in number, superior and inferior. Arising from the musculo-spiral nerve before it pierces the external intermuscular septum, these branches pierce the deep fascia close together on the outer side of the arm in its lower half. Descending over the back of the external condyle, the *superior branch* supplies the skin of the outer side and back of the arm in its lower third, and the back of the forearm in its upper half. The *inferior branch* supplies an area of skin on the back of the forearm in the upper two-thirds internal to the area innervated by the musculo-cutaneous nerve (Fig. 498, p. 630).

2. **Muscular branches.**—The musculo-spiral nerve, as it lies in the interval between the brachialis anticus and brachio-radialis, supplies a small branch to the brachialis anticus (which in some cases is not present) and nerves to the brachio-radialis and extensor carpi radialis longior. It may also provide the nerve to the extensor carpi radialis brevior.

Radial Nerve.

The **radial nerve** (r. superficialis) is entirely cutaneous in its distribution. Arising in the hollow of the elbow beneath the brachio-radialis, it courses downwards under cover of that muscle through the upper two-thirds of the arm, and accompanies the radial artery in the middle third of the forearm. It then passes backwards beneath the tendon of the brachio-radialis and pierces the deep fascia in the outer side of the forearm in the lower third. It is distributed to the skin of the back of the wrist, the outer side and the back of the hand, and the back of the thumb and outer two and a half fingers (Fig. 498, p. 630). Its branches communicate on the ball of the thumb with the musculo-cutaneous nerve, and on the back of the hand with the dorsal branch of the ulnar nerve. The digital branches are small, and are five in number. Two pass to the back of the thumb and reach the inter-phalangeal articulation. One supplies the radial side of the index finger as far as the second phalanx. The remaining two branches divide at the clefts between the second and third, and third and fourth fingers respectively, and innervate the adjacent sides of these fingers as far as the second phalanx. The rest of the skin of these digits to the tips is supplied by digital branches of the median nerve. The nerve may only supply one and a half fingers, being replaced by branches from the ulnar nerve.

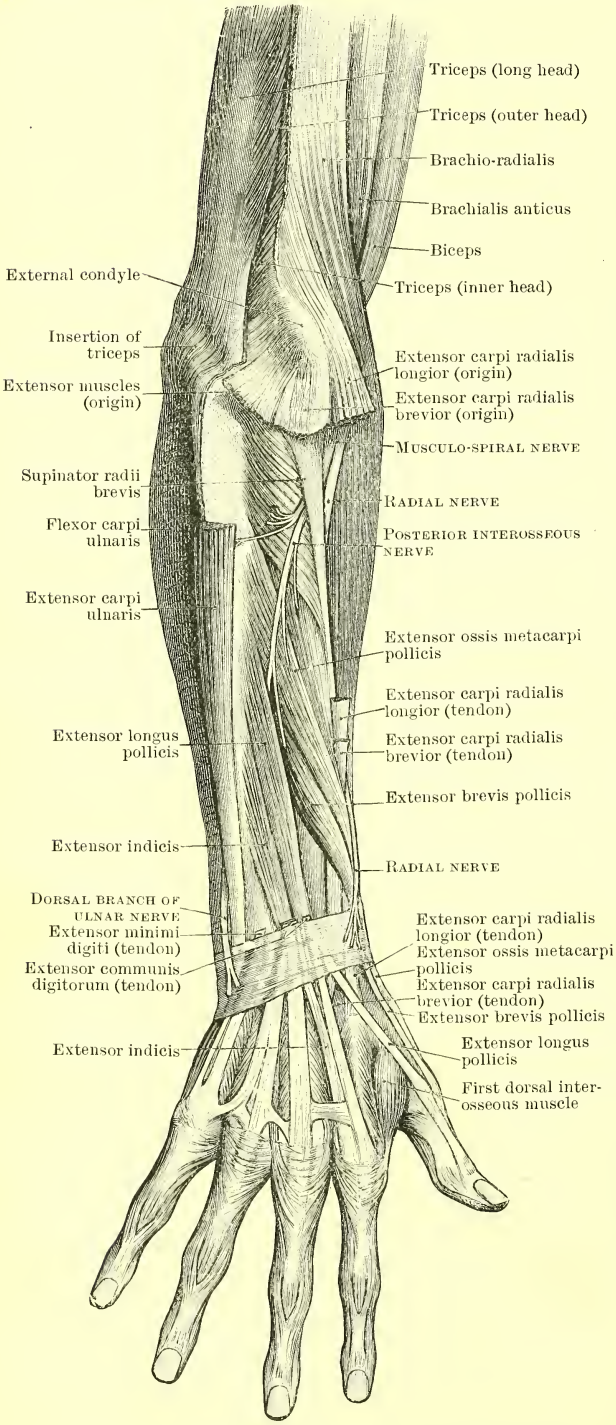


Fig. 501.—The Muscles of the Back of the Forearm (the superficial muscles have been reflected).

Posterior Interosseous Nerve.

The **posterior interosseous nerve** (r. profundus, n. interosseus antibrachii dorsalis) is entirely muscular and articular in its distribution, and it arises like the radial beneath the brachio-radialis muscle. Directed obliquely downwards and backwards, it

reaches the back of the forearm, after passing round the outer side of the radius, by piercing the fibres of the supinator radii brevis muscle (Fig. 501). On the back of the forearm it is placed in the upper part of its course beneath the superficial extensor muscles, and upon the supinator radii brevis and extensor ossis metacarpi pollicis, along with the posterior interosseous artery. In the lower half of the forearm it passes beneath the extensor longus pollicis, and lies upon the interosseous membrane. At the wrist it passes beneath the extensor tendons on to the back of the carpus, where it terminates in a gangliform enlargement of small size, from which branches pass to the inter-carpal articulations. The posterior interosseous nerve supplies the following branches:—

(1) Terminal **articular branches** to the carpal joints.

(2) **Muscular branches**, in its course through the forearm. Thus on the outer side of the radius it supplies the extensor carpi radialis brevior and the supinator brevis muscle before it enters the fibres of the last-named muscle. After emerging from the supinator brevis it supplies a large bundle of nerves which enter the extensor communis digitorum, extensor minimi digiti, and extensor carpi ulnaris near their origins. Lower down the forearm the nerve gives off branches to the extensor ossis metacarpi pollicis, extensor longus and extensor brevis pollicis, and extensor indicis.

Subscapular Nerves.

There are three subscapular nerves (nn. subscapulares) (Figs. 494 and 496).

The **first or short subscapular nerve** is generally double, and there may be three trunks present. It arises from the posterior cord of the plexus behind the circumflex nerve, and comes from the fifth and sixth cervical nerves. It passes downwards behind the axillary artery and enters the subscapularis muscle.

The **second or lower subscapular nerve** also arises behind the circumflex from the posterior cord of the plexus, and from the fifth and sixth cervical nerves. Its origin is below and external to that of the first nerve. It courses outwards and downwards behind the axillary artery, and the circumflex and musculo-spiral nerves to the teres major muscle. It supplies branches to the outer part of the subscapularis muscle and ends in the teres major.

The **third or long subscapular nerve** (n. thoraco-dorsalis) arises from the back of the posterior cord of the plexus, behind the musculo-spiral nerve, and from the sixth, seventh, and eighth cervical nerves, or from the seventh and eighth nerves only. It is directed downwards and outwards between the two previous nerves, behind the axillary artery and over the posterior wall of the axilla, in company with the subscapular artery, to the latissimus dorsi muscle, which it supplies on its anterior (inner) surface.

THORACIC NERVES.

The thoracic nerves are twelve in number, each nerve emerging below the corresponding vertebra and rib. Eleven of the series are intercostal, the twelfth lying below the last rib. The first, second, third, and twelfth nerves present peculiarities in their course and distribution. The other thoracic nerves, as already stated, are simple, and may be regarded as types both in course and distribution.

The **first thoracic nerve** is the largest of the series. It emerges from the spinal canal below the neck of the first rib, and divides in the first intercostal space into two very unequal, upper and lower, parts. The *upper* larger part ascends obliquely over the neck of the first rib, lying external to the superior intercostal artery, and enters the neck behind the subclavian artery and the pleura. It proceeds outwards upon the scalenus medius muscle and enters into the formation of the brachial plexus, as already described.

The *lower, intercostal part* of the nerve is much smaller in size. It courses forwards in the first intercostal space and supplies the intercostal muscles. It usually gives off no anterior branch to the skin of the chest and no lateral cutaneous branch.

In some cases a lateral cutaneous branch emerges from the side of the first intercostal space. This may be derived from the first nerve, or it may be the **intercosto-humeral nerve**, derived from the second thoracic nerve. In many cases an anterior cutaneous branch perforates the first intercostal space and supplies the skin on the front of the chest. This branch, similarly, is sometimes traceable to the second thoracic nerve.

Communications.—Besides its junction with the eighth cervical to form the brachial plexus, the first thoracic nerve effects the following communications:—(*a*) The last cervical or first thoracic ganglion of the sympathetic sends a gray ramus communicans to join the nerve on its appearance in the thorax. (*b*) The second thoracic nerve in a majority of cases communicates with the first. This communication varies considerably in size and distribution. It may reinforce the intercostal branch of the nerve, it may send one branch to the intercostal portion and another to the part of the nerve joining the brachial plexus, or it may consist of a nerve proceeding solely to join the brachial plexus by a junction in the first intercostal space with the part of the first thoracic nerve, which is engaged in forming the plexus. (*c*) It is possible that the first *white ramus communicans* in the thoracic region connects the first thoracic nerve with the gangliated cord of the sympathetic, but this is not known with certainty.

The **second thoracic nerve** is of large size, though much smaller than the first. It passes forwards in the second intercostal space, lying at first in the subcostal groove between the external and internal intercostal muscles. At the level of the mid-axillary line it gives off a large lateral branch; continuing its course it pierces the internal intercostal muscle and lies upon the pleura; finally, at the lateral border of the sternum, it passes forwards in front of the internal mammary artery and through the internal intercostal muscle, and the aponeurosis of the external intercostal muscle, and ends by supplying the skin of the front of the chest over the second intercostal space.

The nerve supplies the following branches:—

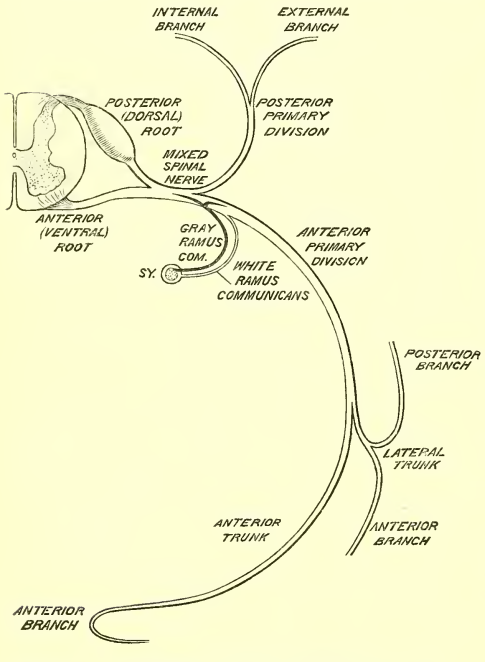


FIG. 502.—SCHEME OF THE DISTRIBUTION OF A TYPICAL SPINAL NERVE.

1. **Muscular branches** to the muscles of the second intercostal space.

2. **Cutaneous branches.** (*a*) **Anterior terminal branches** (rr. cutaneus anterior) to the skin over the second intercostal space (Fig. 503). (*b*) A large lateral cutaneous branch, the **intercosto-humeral nerve** (n. intercosto-brachialis) (Fig. 494, p. 623). This nerve pierces the intercostal muscles and the serratus magnus, and, crossing the axilla, extends to the arm. It pierces the deep fascia just beyond the posterior fold of the axilla, and can be traced down the arm as far as the interval between the internal condyle of the humerus and the olecranon process. It supplies an area of skin stretching across the armpit and along the posterior surface of the arm on the inner side as far as the elbow (Fig. 497, p. 628).

The intercosto-humeral nerve varies in size. It may pierce the first intercostal space, and it is often divisible into anterior and posterior branches, like the lateral branch of an ordinary intercostal nerve.

Communications.—(1) The intercosto-humeral nerve communicates with two adjacent nerves. Either before or after piercing the fascia of the axilla it is joined by the lesser internal cutaneous nerve of the brachial plexus. It also communicates with the posterior part of the lateral branch of the third intercostal nerve by means of the branches distributed to the floor and boundaries of the axilla. It may supply the axillary arches, when present. (2) Besides the branches referred to, the second thoracic nerve in many

cases transmits a nerve to the brachial plexus, which becomes incorporated with the first thoracic nerve after passing over the neck of the second rib. This branch is inconstant. As already mentioned, it may join only the intercostal part of the first thoracic nerve, it may join the brachial plexus only, or it may send branches to both parts of the first thoracic nerve. (3) Besides the communications effected by branches of the second thoracic nerve in its course, it also receives a *gray ramus communicans* from the second thoracic ganglion of the sympathetic cord in the thorax. It probably also sends to the sympathetic the first *white ramus communicans*, though this is not known with certainty.

The **third thoracic nerve** only differs from a typical thoracic nerve in one respect. Its **lateral branch** divides in the usual way into anterior and posterior parts, of which the latter is carried to the arm and supplies an area of skin on the posterior half of the inner side near the root of the limb. It effects a junction with the intercosto-humeral nerve (Fig. 494, p. 623).

The **fourth, fifth, and sixth thoracic nerves** have a course and distribution which is simple and typical. Except for the peculiarities above mentioned, the second and third thoracic nerves have a similar distribution.

The nerves appear on the posterior wall of the thorax, in the subcostal groove of the corresponding rib. They extend forwards between the intercostal

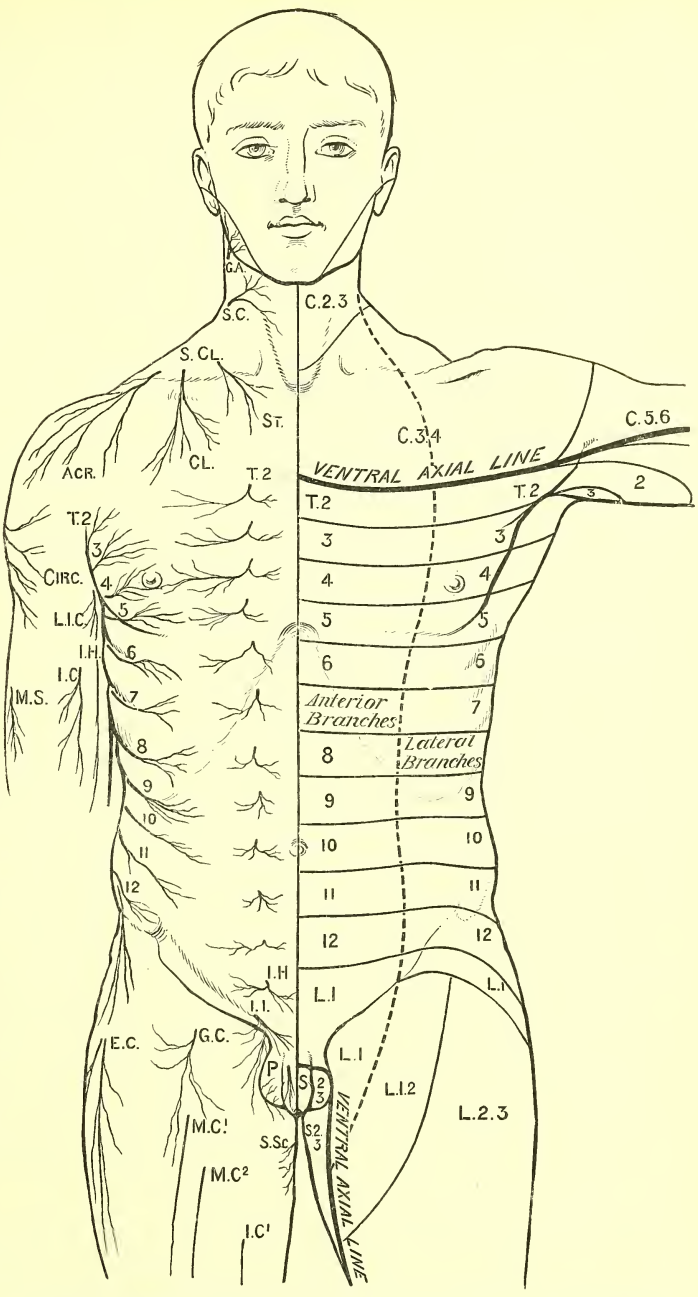


FIG. 503.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A, Great auricular nerve; S.C, Superficial cervical nerve; S.CL, Supraclavicular nerves; ACR, Acromial; CL, Clavicular; ST, Sternal; T.2-12, Lateral and anterior branches of thoracic nerves; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; CIRC, Cutaneous branch of circumflex nerve; L.I.C, Lesser internal cutaneous nerve; I.H, Intercosto-humeral; I.C, Internal cutaneous; M.S, Cutaneous branch of musculo-spiral nerve, E.C, External cutaneous nerves; G.C, Genito-crural nerve; M.C¹ ², Middle cutaneous nerves; I.C¹, Branch of internal cutaneous nerve; P, Branches of pudic nerve; S.SC, Branches of small sciatic nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

muscles as far as the middle of the chest wall, lying at a lower level than the intercostal vessels. At the side of the chest each nerve passes obliquely through the internal intercostal muscle, and comes to lie upon the pleura, triangularis sterni muscle, and internal mammary artery. Thereafter, piercing the fibres of the internal intercostal muscle and the aponeurosis of the external intercostal muscle, each nerve ends by supplying the skin of the front of the chest, over an area corresponding to the inner or anterior part of the intercostal space to which it belongs.

Branches.—Each intercostal nerve supplies, in addition to the anterior terminal cutaneous branches, *muscular branches* to the intercostal muscles and a **lateral trunk** (r. cutaneus, lateralis), which, piercing the intercostal muscles and the serratus magnus, divides into anterior and posterior branches for the innervation of the skin over the side of the chest. Each area of skin thus innervated is continuous anteriorly with the area innervated by the anterior terminal branches of the same nerves, and posteriorly with the areas supplied by their posterior primary divisions.

The upper six intercostal nerves supply the muscles of the first six intercostal spaces and the triangularis sterni (3, 4, 5, 6). The second, third, fourth, fifth, and sixth nerves supply the skin of the front of the chest: the second, opposite the manubrio-sternal joint; the sixth, opposite the base of the xiphoid cartilage. Their lateral branches supply branches to the intercostal muscles and the skin of the side of the chest, the second (intercosto-humeral) and the third in part being drawn out on to the arm. The fourth supplies the nipple (Fig. 503).

Communications.—Each of these intercostal nerves communicates with the sympathetic cord and ganglia by two branches—a *white ramus communicans* to the corresponding sympathetic ganglion or the adjacent part of the sympathetic cord; and a *gray ramus communicans*, which passes to each nerve from the corresponding ganglion.

The **seventh, eighth, ninth, tenth, and eleventh thoracic nerves** only differ from the preceding nerves in regard to a part of their course and distribution. Each has the same course and communications as the preceding nerves in the thoracic wall. In addition, these nerves have a further course and distribution in the abdominal wall. Each nerve traverses its intercostal space in the way described. At the anterior end of the space, the nerve pierces the attachment of the diaphragm and the transveralis abdominis muscles to the costal cartilages, and courses forwards in the abdominal wall between the transversalis and obliquus internus muscles. The nerve then passes between the rectus muscle and the posterior layer of its sheath, and eventually reaches the anterior abdominal wall and becomes cutaneous by piercing the rectus itself and the anterior layer of its sheath.

Muscular Branches.—The lower intercostal nerves supply the intercostal muscles of the spaces in which they lie; and in the abdominal wall they innervate the transversalis, obliqui, and rectus abdominis. The branches arise from the main trunk as well as from its lateral and anterior branches. (The ninth, tenth, and eleventh nerves are described as assisting in the innervation of the diaphragm by communications with the phrenic nerve.)

Cutaneous Branches.—These are lateral and anterior. The **lateral branches** divide into anterior and posterior parts, and, becoming superficial along the line of inter-digitation of the obliquus externus muscle with the serratus magnus and latissimus dorsi, they are directed more obliquely downwards than the lateral branches of the higher intercostal nerves, and are distributed to the skin of the loin as low down as the buttock. The lateral branch of the eleventh nerve can be traced over the iliac crest (Fig. 503).

The **anterior branches** are small. That of the seventh nerve innervates the skin at the level of the ensiform cartilage. The eighth and ninth appear between the ensiform cartilage and the umbilicus; the tenth nerve supplies the region of the umbilicus; and the eleventh, the area immediately below the umbilicus.

The cutaneous branches of these nerves, including the posterior primary divisions, thus supply continuous belts of skin, which can be mapped out on the body from the vertebral column behind to the middle line in front. These areas are not placed horizontally, but tend to be drawn downwards as the series is followed from the upper to the lower nerves.

The **twelfth thoracic nerve** is peculiar in its course and distribution. It

emerges below the last rib (Fig. 504), and passes outwards and downwards in the posterior abdominal wall under cover of the psoas muscle, and between the external arcuate ligament and the quadratus lumborum muscle; it pierces the transversalis muscle, and courses forwards in the interval between it and the obliquus internus as far as the sheath of the rectus muscle. After piercing the posterior layer of the sheath, the rectus muscle, and the anterior layer of the sheath, it terminates by supplying the skin of the anterior abdominal wall midway between the umbilicus and the pubis. The branches of the nerve are **muscular**, to the transversalis, obliqui, rectus, and pyramidalis muscles of the abdominal wall, and **cutaneous branches**, two in number—an *anterior terminal branch*, which supplies the skin of the anterior abdominal wall midway between the umbilicus and the pubis, and a large *lateral cutaneous* (iliac) *branch*, which, passing obliquely downwards through the lateral muscles of the abdominal wall, becomes superficial above the iliac crest, a couple of inches behind the anterior superior spine. It supplies the skin of the buttock as far down as a point below and in front of the great trochanter of the femur (Fig. 507, p. 645).

The twelfth thoracic nerve, in many cases, receives a **communicating branch** from the eleventh, near its origin, and still more frequently sends a fine branch to join the origin of the first lumbar nerve in the psoas muscle. It may communicate also with the ilio-hypogastric nerve, as they lie together in the abdominal wall.

THE LUMBO-SACRAL PLEXUS.

The lumbo-sacral plexus is formed by the union of the anterior primary divisions of the remaining spinal nerves — five lumbar, five sacral, and one coccygeal. Frequently, a fine communicating branch of the twelfth thoracic nerve joins the first lumbar nerve near its origin.

Of the nerves in question the first sacral is generally the largest in size, the nerves diminishing gradually above and rapidly below the first sacral. The plexus, for the most part, forms the nerves destined for the supply of the lower limb. In addition, however, nerves arise at its upper limit which are distributed to the trunk above the level of the limb, and at the lower end of the plexus nerves arise for the supply of the perineum.

Partly for convenience of description, and partly on account of the differences in position and course of some of the nerves emanating from it, the plexus is subdivided into three subordinate parts — lumbar, sacral or sciatic, and pudendal plexuses. There is, however, no strict line of demarcation between the three parts.

The **lumbar plexus** is formed by the first four lumbar nerves, and is often joined by a branch from the twelfth thoracic nerve as well. It is limited below by the fourth lumbar nerve (n. furcalis), which also enters into the composition of the sciatic or sacral plexus. The nerves of the lumbar plexus are formed in the loin, and supply that region as well as part of the lower limb. They are separated from the nerves of the sacral portion of the plexus by the articulation of the innominate bone with the sacrum.

The **sacral** or **sciatic plexus** is formed by the fourth and fifth lumbar, and the first two or three sacral nerves. It is generally limited below by the third sacral nerve (n. bigeminus), which also assists in forming the pudendal plexus. The nerves of the sacral plexus are placed on the posterior wall of the pelvis, and are destined almost entirely for the lower limb.

The **pudendal plexus** is formed by the second, third, fourth, and fifth sacral nerves, and the minute coccygeal nerve. It is placed on the back wall of the pelvis and supplies branches mainly to the perineum.

Communications with the Sympathetic.—Each of these nerves has communications with the gangliated cord of the sympathetic in the abdomen and pelvis.

Gray Rami Communicantes.—From the lumbar and sacral ganglia long slender *gray rami communicantes* are directed backwards and outwards over the bodies of the vertebræ, and (in the lumbar region) beneath the origins of the psoas muscle, to reach the anterior primary divisions of the nerves. These branches are irregular in their arrangement. A given nerve may receive branches from two ganglia, or one ganglion may send branches to two nerves. The rami are longer in the loin than in the pelvis, owing to the projection of the lumbar portion of the vertebral column.

White Rami Communicantes.—Certain lumbar and sacral nerves are also connected with the abdominal and pelvic sympathethic by means of *white rami communicantes*. From the first two, and possibly also the third and fourth lumbar nerves, white rami communi-

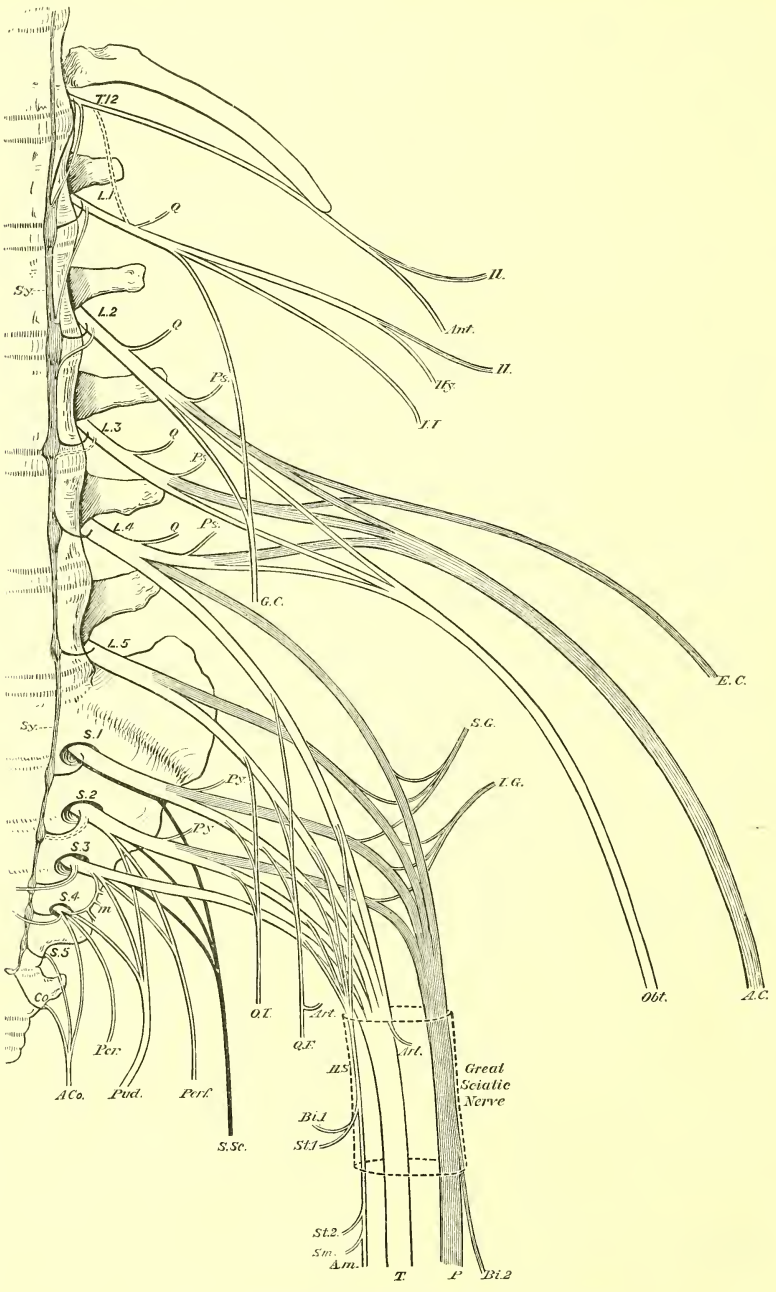


Fig. 504.—Nerves of the Lumbo-Sacral Plexus.

Sy, Sympathetic cord ; T.12, L.1, 2, 3, 4, 5, S.1, 2, 3, 4, 5, Co, Anterior primary divisions of the last thoracic, the lumbar, sacral, and coccygeal nerves ; Q, Nerves to quadratus lumborum ; Ps, Nerves to psoas muscle ; G.C, Genito-crural nerve ; Il, Iliac branches of last thoracic and ilio-hypogastric nerves ; Hy, Hypogastric branch of Ilio-hypogastric nerve ; I.I, Ilio-inguinal nerve ; E.C, External cutaneous nerve ; A.C, Anterior crural nerve ; Obt, Obturator nerve ; Py, Nerves to pyriformis muscle ; O.I, Nerve to obturator internus ; Q.F, Nerve to quadratus femoris muscle ; Art, Articular branch ; S.G, Superior gluteal nerve ; I.G, Inferior gluteal nerve ; P, Peroneal nerve ; Bi.2, Nerve to short head of biceps muscle ; T, Tibial nerve ; Art, Articular branch ; H.S, Nerve to the hamstring muscles ; Bi.1, Nerves to biceps (long head), and St.1, to semitendinosus ; St.2, Semitendinosus ; Sm, Semimembranosus ; A.m, Adductor magnus ; S.Sc, Small sciatic nerve ; Perf, Perforating cutaneous nerve ; Pud, Pudic nerve ; M. Muscular branches ; Per, Perineal branch of fourth sacral ; A.Co, Anterior sacro-coccygeal nerve.

cantes are directed forwards, either independently or incorporated with the corresponding gray rami, to join the upper part of the lumbar gangliated cord. The fifth lumbar nerve and the first sacral nerves are unprovided with white rami communicantes. From the third, and usually also the second or fourth sacral nerves, white rami (visceral branches) pass inwards, and, crossing over (without joining) the gangliated cord, enter the pelvic plexus of the sympathetic. The fifth sacral and coccygeal nerves possess no white rami communicantes.

THE LUMBAR PLEXUS.

The lumbar plexus is formed by the anterior primary divisions of the first three

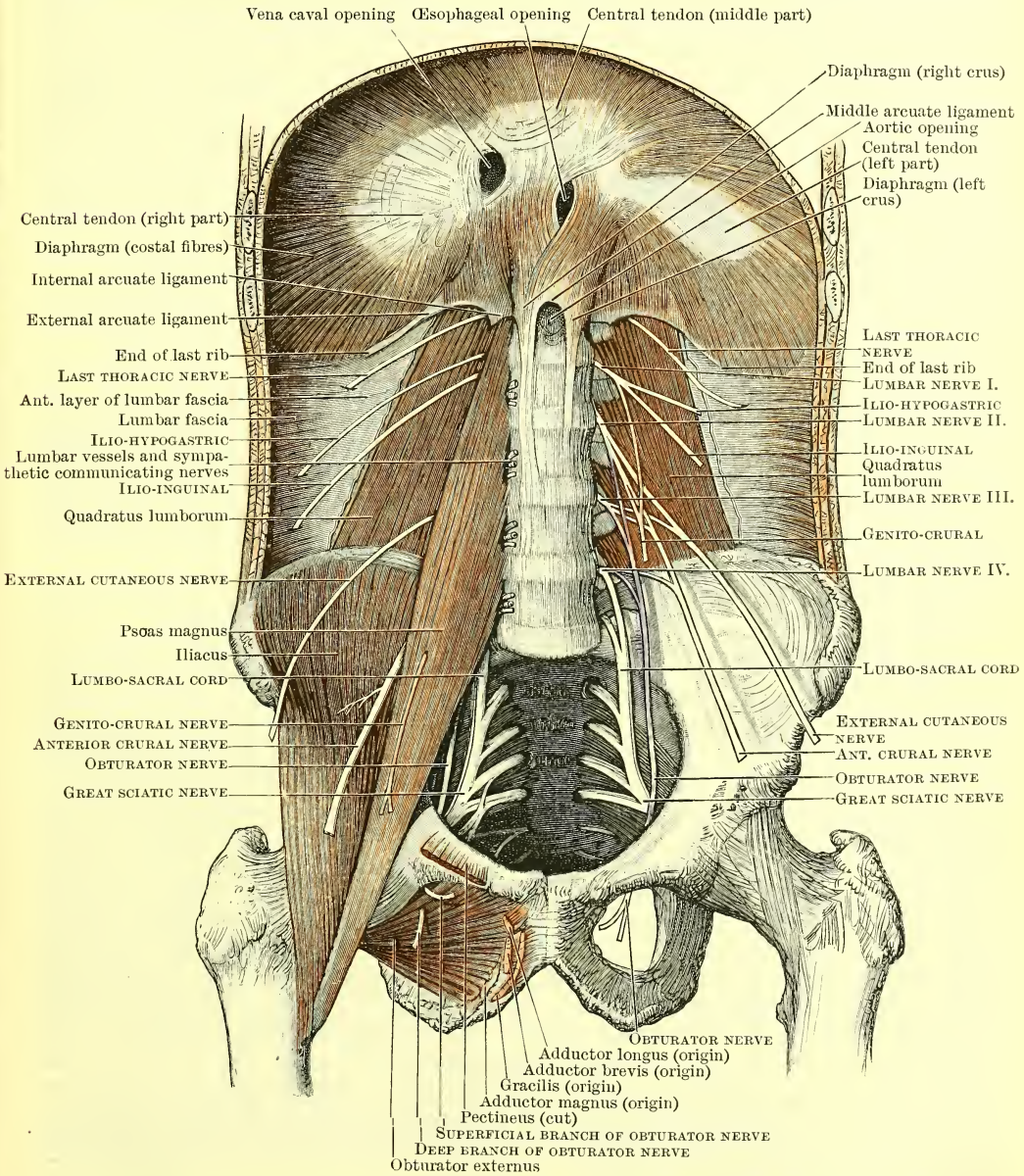


Fig. 505.—View of the Posterior Abdominal Wall, to show the Muscles and the Nerves of the Lumbo-Sacral Plexus.

and a part of the fourth lumbar nerves, with the addition, in some cases, of a small branch from the twelfth thoracic nerve. The nerves increase in size from above downwards (Fig. 505).

Position and Constitution.—The plexus is placed deeply in the substance of the psoas muscle, in front of the transverse processes of the lumbar vertebræ. The

nerves, on emerging from the intervertebral foramina, are connected as above described with the sympathetic system, and then divide in the following manner in the substance of the psoas muscle. The first and second nerves divide into upper and lower branches. The upper branch of the first nerve (which may be joined by the branch from the twelfth thoracic nerve) forms two nerves, **ilio-hypogastric** and **ilio-inguinal**. The lower branch of the first joins the upper branch of the second nerve, to produce the **genito-crural nerve**. The lower branch of the second nerve, the whole of the third, and that part of the fourth nerve engaged in the constitution of the plexus divide each into two unequal parts—smaller *anterior* and larger *posterior parts*. The smaller anterior portions combine together to form the **obturator nerve**, which is thus formed by the second, third, and fourth lumbar nerves. The root from the second nerve is not always present. The larger posterior portions of the same nerves combine together to form the **anterior crural nerve**. From the back of the posterior parts of the second and third nerves, the **external cutaneous nerve** arises. The nerves also provide, near their origins, irregular **muscular branches**, for the psoas and quadratus lumborum muscles. The following is a list of the nerves which spring from the lumbar plexus (Figs. 504 and 505):—

(1) Muscular branches to the quadratus lumborum and psoas.
(2) Ilio-hypogastric.
(3) Ilio-inguinal.
(4) Genito-crural.
(5) External cutaneous.
(6) Obturator.
(7) Anterior crural.

Muscular Branches.—The nerves to the **quadratus lumborum muscle** arise independently from the first three or four lumbar nerves (and sometimes also from the twelfth thoracic nerve). The nerves to the **psoas muscles** arise from the second and third lumbar nerves, with additions, in some cases, from the first or fourth. They are often associated in their origin with the nerve to the iliacus from the anterior crural. The **psoas minor**, when present, is innervated by the first or second lumbar nerve.

The ilio-hypogastric and ilio-inguinal nerves closely resemble in their course and distribution the lower thoracic nerves, with which they are in series.

The **ilio-hypogastric nerve** (n. ilio-hypogastricus) is the highest branch of the first lumbar nerve. It receives fibres also from the twelfth thoracic, when that nerve communicates with the first lumbar nerve. After traversing the psoas muscle obliquely, it appears at its outer border on the surface of the quadratus lumborum and behind the kidney. It courses through the loin, lying between the transversalis and obliquus internus muscles, above the crest of the ilium. About an inch in front of the anterior superior spine it pierces the obliquus internus, and continues its course ~~in the groin~~ beneath the aponeurosis of the obliquus externus. It finally becomes cutaneous in the anterior abdominal wall, by piercing the aponeurosis of the obliquus externus about an inch and a half above the external abdominal ring (Fig. 507 p. 645).

Its **branches** are—(1) *muscular* to the muscles of the abdominal wall; and (2) *cutaneous branches*, two in number. The **iliac branch** corresponds with the lateral branch of an intercostal nerve, and, after piercing the obliquus internus and obliquus externus, becomes cutaneous just above the iliac crest, below and behind the iliac branch of the last thoracic nerve. It is small, and may be absent. It is distributed to the skin over the upper part of the outer side of the buttock, in continuity with the cutaneous branch of the posterior primary division of the first lumbar nerve. The **hypogastric branch** is the anterior terminal branch of the nerve. It supplies the skin of the anterior abdominal wall below the level of the last thoracic nerve and above the pubis.

The **ilio-inguinal nerve** (n. ilio-inguinalis) is the second branch given off from the first lumbar nerve. It also may receive fibres from the last thoracic nerve. Not unfrequently the ilio-hypogastric and ilio-inguinal nerves are represented for a longer or shorter part of their course by a single trunk. When separate the nerve takes a course similar to that of the ilio-hypogastric nerve, but at a lower level, as far as the anterior abdominal wall. It then pierces the obliquus internus farther forward and lower down than the ilio-hypogastric; and coursing forwards

beneath the aponeurosis of the obliquus externus, just above Poupart's ligament, it becomes superficial after passing through the external abdominal ring and external spermatic fascia (Fig. 507, p. 645).

Its branches are *muscular* to the muscles of the abdominal wall, among which it passes, and *cutaneous branches,* which innervate the skin (1) of the anterior abdominal wall over the symphysis pubis, (2) of the thigh over the upper and inner part of Scarpa's triangle, and (3) of the upper part of the scrotum, and root and dorsum of the penis (of the mons Veneris and labium majus in the female). These last-named branches are contiguous to branches of the pudendal and pudic nerves. No lateral cutaneous branch arises from the ilio-inguinal nerve. It thus corresponds, like the hypogastric part of the ilio-hypogastric nerve, to the anterior trunk of a typical thoracic nerve.

The **genito-crural nerve** (n. genito-femoralis) usually arises by two independent roots from the front of the first and second lumbar nerves, which unite in the substance of the psoas to form a slender trunk. It appears on the posterior abdominal wall, lying on the psoas magnus, internal to the psoas parvus, and, piercing the psoas fascia, it extends downwards on the outer side of the common and external iliac vessels and behind the ureter to Poupart's ligament (Fig. 505, p. 641). At a variable point above that ligament it divides into genital and crural branches. The **genital branch** is a minute nerve. It crosses the terminations of the external iliac vessels, and, along with the vas deferens and spermatic vessels, enters the inguinal canal through the internal abdominal ring. It terminates by supplying small branches to the skin of the scrotum and adjacent part of the thigh. In the female it accompanies the round ligament to the labium majus. This nerve gives off in its course the following small branches: (1) to the external iliac artery; (2) to the cremaster muscle; (3) to communicate with the spermatic plexus of the sympathetic. The **crural branch** continues the course of the parent nerve into the thigh, lying on the outer side of the femoral artery. It becomes cutaneous by passing through the saphenous opening or the iliac portion of the fascia lata, and supplies an area of skin over Scarpa's triangle, external to that supplied by the ilio-inguinal nerve (Fig. 507, p. 645). It communicates in the thigh with the middle cutaneous branch of the anterior crural nerve. Before piercing the deep fascia it gives a minute branch to the femoral artery.

The **external cutaneous nerve** (n. cutaneus femoris lateralis) is only distributed to skin (Fig. 505). It arises from the back of the lumbar plexus, and usually from the second and third lumbar nerves. Emerging from the psoas muscle at its outer border, the nerve crosses the iliacus muscle, beneath the fascia iliaca, to reach the anterior superior iliac spine. It enters the thigh beneath the outer extremity of Poupart's ligament, and either over, under, or through the origin of the sartorius muscle. It extends down the outer side of the front of the thigh for a few inches, lying at first beneath the fascia lata, and afterwards in a tubular investment of the fascia. It gives off small branches in this part of its course, and finally, piercing the fascia about four inches below the anterior superior iliac spine, it separates into anterior and posterior terminal branches. The **anterior branch** is the larger, and is distributed on the outer side of the front of the thigh almost to the knee. The smaller **posterior branch** supplies the skin of the outer side of the buttock below the great trochanter and of the upper two-thirds of the outer side of the thigh (Fig. 507, p. 645).

Obturator Nerve.

The **obturator nerve** (n. obturatorius) supplies the muscles and skin on the inner side of the thigh. It arises in the substance of the psoas muscle by three roots placed in front of those of the anterior crural nerve, and derived from the second, third, and fourth lumbar nerves (Fig. 505, p. 641). Sometimes the root from the second nerve is absent. Passing vertically downwards, the nerve emerges from the psoas at its inner border, behind the common iliac, and on the outer side of the internal iliac vessels. It passes forwards below the pelvic brim in company with the obturator artery to the obturator groove of the thyroid foramen, through which it reaches the thigh. While in the obturator groove it separates into its two main branches, named superficial and deep (Fig. 506, p. 644).

The **superficial branch** enters the thigh in front of the obturator externus and adductor brevis muscles, and beneath the pectineus and adductor longus. In the middle third of the thigh it is found coursing along the inner border of the adductor longus, anterior to the gracilis; and it finally divides into two slender terminal filaments, of which one enters Hunter's canal and ends on the femoral artery, while the other supplies the skin for a variable distance on the inner side of the thigh and joins in the obturator (sub-sartorial) plexus.

The branches of the superficial part of the nerve are :—

1. An **articular branch** to the hip-joint which arises from the nerve as soon as it enters the thigh, and supplies the joint through the acetabular notch.

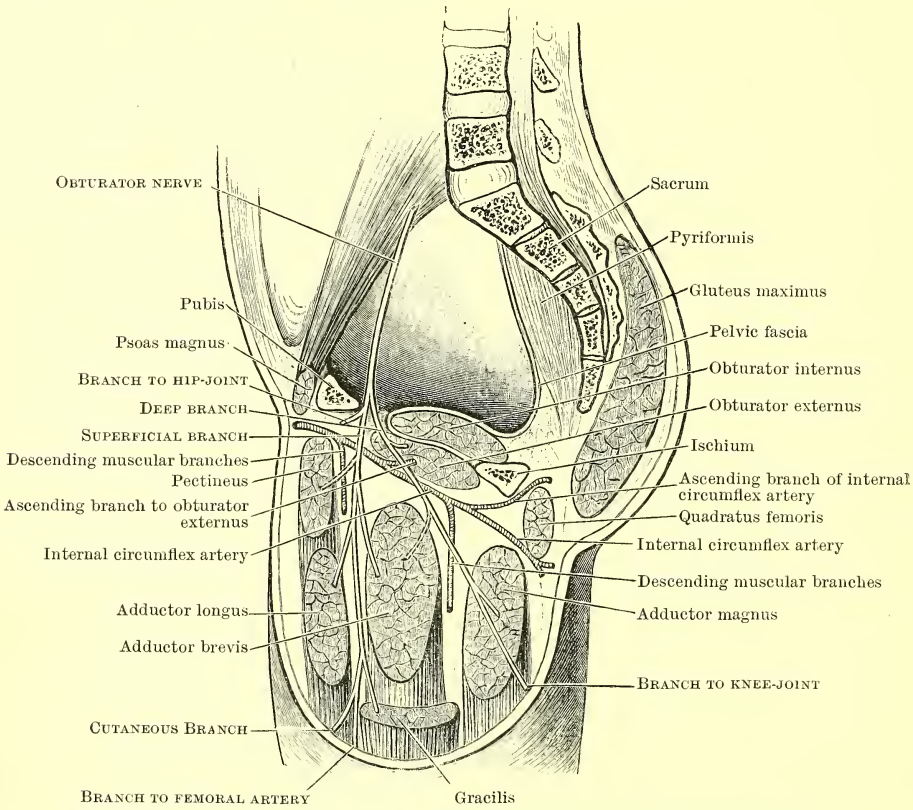


Fig. 506.—Scheme of the Course and Distribution of the Obturator Nerve.

2. **Muscular branches** to the adductor longus, gracilis, adductor brevis (usually), pectineus (occasionally). The last-named muscle is not usually supplied from the obturator nerve.

3. A **cutaneous branch** of very variable size forms one of the terminal branches (Fig. 507). It becomes superficial between the gracilis and adductor longus, in the middle third of the thigh, and may supply the skin of the lower two-thirds of the thigh in its inner side. It is generally of small size, and is connected with branches of the internal cutaneous and internal saphenous nerves behind the sartorius muscle to form the **obturator (sub-sartorial) plexus.** The branch from the internal saphenous nerve to the plexus passes inwards behind the sartorius after piercing the aponeurotic covering of Hunter's canal. The branch from the internal cutaneous nerve is generally superficial at the point of formation of the plexus.

4. The **branch to the femoral artery** is the other terminal branch of the nerve. It enters Hunter's canal along the inner edge of the adductor longus, and ramifies over the lower part of the artery.

5. A fine **communicating branch** sometimes joins the anterior crural nerve in front of the hip-joint.

The **deep part of the obturator nerve** reaches the thigh by piercing the

obturator externus muscle. It passes downwards between the adductor brevis and adductor magnus muscles. After passing obliquely through the adductor magnus, it appears in the popliteal space on the popliteal vessels, and terminates by piercing the posterior ligament and supplying the knee-joint.

Its branches are:—(1) **muscular branches** to the obturator externus, adductor magnus, and (when the muscle is not supplied by the superficial part of the nerve) the adductor brevis. The branch to the obturator externus arises before the nerve enters the muscle, in the obturator groove. The nerve to the adductor magnus is given off as the obturator nerve passes through the substance of the muscle. (2) An **articular terminal branch** is supplied to the back of the knee-joint.

Anterior Crural Nerve.

The **anterior crural nerve** (n. femoralis) is the great nerve for the muscles and skin of the front of the thigh. It arises in the substance of the psoas muscle, from the back of the second, third, and fourth lumbar nerves, behind the obturator nerve. Passing obliquely through the psoas muscle, it emerges from its outer border in the false pelvis (Fig. 505, p. 641). Passing downwards in the groove between the psoas and iliacus, it enters the thigh beneath Poupart's ligament, external to the femoral sheath and femoral vessels. In Scarpa's triangle it breaks up into a large number of branches, among which the external circumflex artery passes.

The **branches** of the anterior crural nerve, which are (1) muscular, (2) articular, and (3) cutaneous, arise in the following way:—

In the abdomen a muscular branch arises from the outer side of the nerve and enters the iliacus muscle.

In Scarpa's triangle the terminal muscular, articular, and cutaneous branches arise in the form of a large bundle of nerves.

1. The **muscular branches** supply the pectineus, sartorius, and quadriceps extensor. The nerve to the *pectineus* arises close to Poupart's ligament, and coursing obliquely downwards and inwards behind the femoral vessels enters the muscle at its outer border. It is not infrequently double. It sometimes gives off a fine communicating branch to the superficial part of the obturator nerve. The nerves to the *sartorius* are in two sets: an outer short set of nerves associated with the outer part of the middle cutaneous nerve, which enter the upper part of the muscle; and an inner longer set which are associated with the inner part of the middle cutaneous nerve, and supply the middle of the muscle. The parts of the *quadriceps extensor* are supplied by several branches. The vastus externus and rectus femoris are supplied on their deep surface by separate nerves which are accompanied by branches of the external circumflex artery. The crureus muscle is supplied superficially by a nerve which passes through the muscle, and innervates also the subcrureus. It also receives fibres from one of

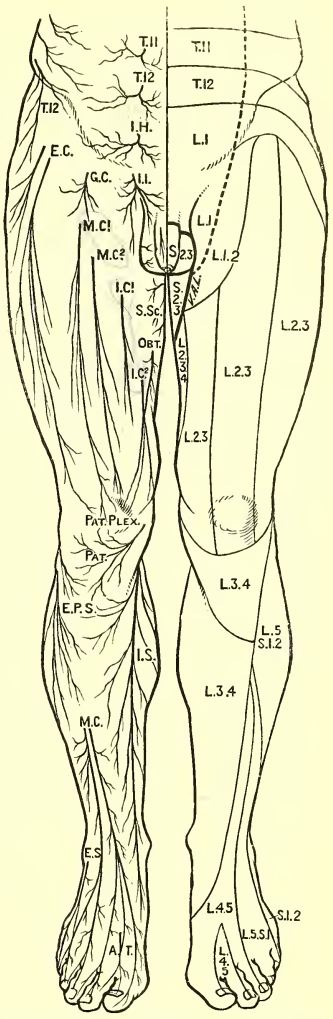


Fig. 507.—Distribution of Cutaneous Nerves on the Front of the Lower Limb.

On the one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

T.11, Branches of eleventh thoracic nerve; T.12, Branches of twelfth thoracic nerve; I.H, Ilio-hypogastric; I.I, Ilio-inguinal; E.C, External cutaneous; G.C, Genito-crural; M.C¹,², Middle cutaneous; I.C¹,², Internal cutaneous; OBT, Obturator; S.Sc, Small sciatic; PAT. PLEX, Patellar plexus; PAT. Patellar branch of internal saphenous; E.P.S, Sural branches of peroneal nerve; I.S, Internal saphenous; M.C, Musculo-cutaneous; E.S, External saphenous; A.T, Anterior tibial.

On the other side a schematic representation is given of the areas supplied by the above nerves, the figures indicating the spinal origin of the branches of distribution to each area.

the nerves to the vastus internus. The vastus internus muscle is supplied by two nerves: an upper trunk, which supplies the higher part of the muscle, and sends fibres to the crureus as well; and a lower trunk, which descends on the outer side of the femoral artery along with the internal saphenous nerve, and passing beneath the sartorius, over or under the aponeurotic covering of Hunter's canal, enters the inner side of the vastus internus muscle. This nerve gives off a small branch which enters the medullary canal of the femur.

2. The **articular branches** supply the hip and knee-joints. The articular branch to the hip-joint arises from the nerve to the rectus femoris, and is accompanied by branches from the external circumflex artery. The articular branches to the knee-joint are four in number. Three of them arise from the nerves to the vastus externus, crureus, and vastus internus, which, after the muscular nerves are given off, are continued downwards to the knee-joint along the front of the femur. A fourth articular branch arises (sometimes) from the internal saphenous nerve.

3. The **cutaneous branches** are the middle and internal cutaneous, and the internal saphenous nerves (Fig. 507).

The **middle cutaneous nerve** arises in two parts, an *external* and an *internal branch*, in the upper part of Scarpa's triangle. The two branches descend vertically and become cutaneous by piercing the fascia lata over the upper third of the sartorius muscle. They carry muscular branches to the sartorius, and the external branch in many cases pierces the muscle. These two nerves supply the skin of the lower three-fourths of the front of the thigh, between the external cutaneous nerve on the outer side and the internal cutaneous on the inner side. They reach down to the front of the patella, and there assist in the formation of the patellar plexus. The external branch communicates in the upper third of the thigh with twigs from the crural branch of the genito-crural nerve.

The **internal cutaneous nerve** lies at first in Scarpa's triangle on the outer side of the femoral vessels. At the apex of the triangle it crosses over the femoral vessels, and is directed downwards over or through the sartorius muscle, and beneath the fascia lata, to the lower third of the thigh. It is distributed to the skin of the lower two-thirds of the thigh on the inner side by means of three branches—upper, middle, and lower.

The *upper branch* may be represented by two or more twigs. It arises from the main nerve near its origin, and pierces the fascia lata near the apex of Scarpa's triangle. It is distributed to the skin of the upper part of the thigh, along the line of the saphenous vein. The *middle* or *anterior branch* is a larger nerve. It separates from the lower branch at the apex of Scarpa's triangle, and passing over the sartorius muscle becomes cutaneous in the middle third of the thigh on the inner side. It supplies the skin of the lower half of the thigh on the inner side, extending as low as the knee, where it joins in the formation of the patellar plexus.

The *lower* or *internal branch* represents the termination of the nerve. It passes down the inner side of the thigh over the sartorius muscle, and communicates in the middle third of the thigh with the internal saphenous and obturator nerves to form the obturator plexus. Piercing the fascia lata on the inner side of the thigh in the lower third, it ramifies over the inner side of the knee, and assists in the formation of the patellar plexus.

The size of the internal cutaneous nerve varies with the size of the cutaneous part of the obturator, and of the internal saphenous nerve.

The **long** or **internal saphenous nerve** (n. saphenus) may be regarded as the terminal branch of the anterior crural nerve. It is destined for the skin of the leg and foot. From its origin in Scarpa's triangle it descends alongside the femoral vessels to Hunter's canal. In the canal it crosses over the femoral sheath from without inwards. At the lower end of the canal, accompanied by the superficial branch of the anastomotic artery, it passes over the tendon of the adductor magnus, and opposite the inner side of the knee-joint becomes cutaneous by passing between the sartorius and gracilis muscles. The nerve then extends down the leg along with the internal saphenous vein, and coursing over the front of the inner ankle it terminates at the middle of the inner border of the foot.

Branches.—1. A **communicating branch** arises in Hunter's canal, and passing

inwards beneath the sartorius joins with branches of the obturator nerve in forming the obturator plexus.

2. The **patellar branch** arises at the lower end of Hunter's canal, and piercing the sartorius muscle is directed downwards and forwards below the patella, and over the inner tuberosity of the tibia to the front of the knee and upper part of the leg. It enters into the formation of the patellar plexus.

3. An **articular branch** sometimes arises from the nerve at the inner side of the knee.

4. The **terminal branches** of the internal saphenous nerve are distributed to the skin of the front and inner side of the leg, and the posterior half of the dorsum and inner side of the foot.

Patellar plexus.—This plexus consists of fine communications beneath the skin in front of the knee, between the branches of the cutaneous nerves supplying that region. The nerves which enter into its formation are the patellar branch of the internal saphenous, internal and middle cutaneous nerves, and sometimes the external cutaneous nerve.

The **accessory obturator nerve** (n. obturatorius accessorius, n. accessorius anterioris cruralis Winslow) is only occasionally present (29 per cent, Eisler). It arises from the third, or third and fourth lumbar nerves, between the roots of the obturator and anterior crural nerves. Associating itself with the obturator, from which, however, it is quite separable, it appears in the abdomen at the inner side of the psoas muscle, and coursing over the pelvic brim behind the external iliac vessels, it leaves the obturator nerve, and enters the thigh in front of the pubis.

In the thigh, behind the femoral vessels, it usually ends in three branches: a nerve which replaces the branch from the anterior crural to the pectineus, a nerve to the hip-joint, and a nerve which communicates with the superficial part of the obturator nerve. In some cases it only supplies the nerve to the pectineus; more rarely it is of considerable size, and reinforces the obturator nerve in the innervation of the adductor muscles.

The accessory obturator nerve was first described by Winslow as the *n. accessorius anterioris cruralis*. Schmidt later described it in great detail, and gave it the name it now bears. It is more closely associated with the anterior crural than with the obturator. Its origin is behind the roots of the obturator: it is separated, like the anterior crural, from the obturator by the pubic bone, and its chief branch, to the pectineus muscle, replaces the normal branch from the anterior crural nerve. On the other hand, for a part of its course it accompanies the obturator, and in rare cases it may replace branches of that nerve.

THE SACRAL OR SCIATIC PLEXUS.

The sacral or sciatic portion of the lumbo-sacral plexus is destined almost entirely for the lower limb. It is usually formed by the anterior primary divisions of a part of the fourth lumbar nerve (n. furcalis), the fifth lumbar, the first, and parts of the second, and third sacral nerves (n. bigeminus).

Communications with the Sympathetic.—Each of the nerves named is connected to the lumbar or pelvic sympathetic by *gray rami communicantes*, as already described; and *white rami communicantes* pass usually from the third and usually also from the second or fourth sacral nerves to join the pelvic plexus of the sympathetic.

Position and Constitution.—The plexus is placed on the back wall of the pelvis between the parietal pelvic fascia and the pyriformis muscle. In front of it are the pelvic colon, the internal iliac vessels, and the ureter.

The plexus is constituted by the convergence of the nerves concerned towards the lower part of the great sacro-sciatic foramen, and their union to form a broad triangular band, the apex of which is continued through the great sacro-sciatic foramen below the pyriformis muscle into the buttock, as the **great sciatic nerve.** From the anterior and posterior surfaces of this triangular band numerous small branches arise, which are distributed to the parts in the neighbourhood of the origin of the nerve.

The great sciatic nerve ends in the thigh by dividing into two large nerves, the **tibial** (internal popliteal), and **peroneal** (external popliteal). In many cases these two nerves are distinct from their origin, and are separated sometimes by fibres of the pyriformis muscle. In all cases on removal of the sheath investing the great sciatic nerve the tibial and peroneal nerves can be traced up to the plexus, from which they invariably take origin by distinct and separate roots.

The descending branch of the fourth lumbar nerve (n. furcalis) after emerging from the inner border of the psoas muscle internal to the obturator nerve, divides

behind the iliac vessels into anterior and posterior (ventral and dorsal) parts, each of which joins a corresponding part of the fifth lumbar nerve. The anterior primary division of the fifth lumbar nerve descends over the ala of the sacrum, and divides into anterior and posterior parts, which are joined by the corresponding parts of the fourth lumbar nerve. The two resulting trunks are sometimes called the **lumbo-sacral cord.** The first and second sacral nerves pass almost horizontally outwards from the anterior sacral foramina, and divide in front of the pyriformis into similar anterior and posterior parts. The third sacral nerve (n. bigeminus) divides into upper and lower parts. The lower part is concerned in forming the pudendal plexus. The upper part is directed outwards, and slightly upwards, towards the preceding nerve, and does not separate into two parts, but remains undivided.

These trunks combine to form the sciatic or sacral plexus, and its main subdivisions, in the following way. Lying in apposition, and converging to the lower part of the great sacro-sciatic foramen, the *posterior* (dorsal) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral cord), and of the first and second sacral nerves, combine to form the **peroneal nerve** and the subordinate nerves which arise from the posterior aspect of the plexus. The *anterior* (ventral) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral cord), and of the first and second sacral nerves, together with that part of the third sacral nerve which is contributed to the plexus, unite to form the **tibial nerve** and the subordinate nerves arising from the front of the plexus.

Of these nerves the fifth lumbar and first sacral are the largest; the others diminishing in size as they are traced upwards and downwards. There is no distinct demarcation between the sacral and pudendal plexuses. The second and third sacral nerves (and in some cases the first sacral also) are concerned in the formation of both plexuses.

Branches.—The nerves of distribution derived from the sacral plexus are divided according to their origin into an *anterior* (ventral) and a *posterior* (dorsal) *series.* Each set comprises one of the two essential terminal parts—peroneal and tibial nerves—of the great sciatic, and numerous smaller collateral branches.

Anterior Branches.	Posterior Branches.
Tibial (internal popliteal) nerve	Peroneal (external popliteal) nerve
Muscular branches—	*Muscular branches*—
Nerves to hamstring muscles	Nerves to short head of biceps
,, quadratus femoris	,, pyriformis
,, gemelli	Superior gluteal nerve
,, obturator internus	Inferior gluteal nerve
Articular branches (to hip-joint)	*Articular branches* (to knee-joint)

Great Sciatic Nerve.

The **great sciatic nerve** (n. ischiadicus).—It has already been shown how this nerve is formed. It comprises the two main nerves of the sacral plexus, bound together by an investing sheath, which contains, in addition to the peroneal and tibial nerves, a subordinate branch of each, the nerve to the hamstring muscles, from the tibial, and the nerve to the short head of the biceps flexor cruris, from the peroneal nerve. A thick band about half an inch in breadth is formed, consisting from within outwards of (1) **nerves to the hamstring muscles**, (2) **tibial** (internal popliteal), (3) **peroneal** (external popliteal), (4) **nerve to the short head of the biceps muscle.** The great sciatic nerve extends through the buttock and the back of the thigh. Forming a continuation of the sacral plexus, it enters the buttock by passing through the great sacro-sciatic foramen, in the interval between the pyriformis and superior gemellus. Concealed by the gluteus maximus muscle, it passes downwards to the thigh, accompanied by the sciatic artery, and the arteria comes nervi ischiadici. It lies in the hollow between the great trochanter of the femur and the tuberosity of the ischium, and enters the thigh beneath the fold of the nates at the lower border of the gluteus maximus. At this spot it is comparatively superficial, lying in the angle between the edge of the gluteus maximus above and externally, and the origins of the hamstring muscles internally. In the thigh it is placed upon the adductor magnus beneath the hamstring muscles, and it terminates at a variable point by dividing into the tibial and peroneal nerves. As

already stated, these two nerves may be separate from their origins, and their separation may occur at any point between the great sacro-sciatic foramen and the upper part of the popliteal space.

The Nerves of Distribution from the Sacral Plexus.

These are divisible into two series—**collateral** and **terminal branches**. Each subdivision consists of a series of *anterior* (ventral) and *posterior* (dorsal) *trunks*.

Collateral Branches.—The *anterior branches* are (*a*) muscular branches (to the quadratus femoris, gemelli, obturator internus, and hamstring muscles); and (*b*) articular branches (to the hip-joint). These nerves all arise from the anterior aspect of the sacral plexus.

The **nerve to the quadratus femoris** (and inferior gemellus) arises from the front of the fourth and fifth lumbar and first sacral nerves. It passes downwards over the back of the capsule of the hip-joint (to which it sends a fine branch) beneath the sacral plexus, gemelli, and obturator internus muscles. It supplies a nerve to the inferior gemellus, and terminates in the deep surface of the quadratus femoris.

The **nerve to the obturator internus** (and superior gemellus) arises from the anterior aspect of the fifth lumbar and first two sacral nerves. In the buttock it lies below the great sciatic nerve on the outer side of the pudic vessels; crossing the ischial spine, it enters the ischio-rectal fossa through the lesser sciatic foramen. The nerve supplies in the buttock a branch to the superior gemellus, and terminates by entering the pelvic surface of the obturator internus.

The **nerve to the hamstring muscles** forms the innermost part of the great sciatic trunk in the lower part of the buttock. It arises from all the roots of the tibial nerve on their anterior aspect, viz., from the fourth and fifth lumbar and the first three sacral nerves. These roots unite to form a cord which is closely associated with the tibial nerve and is placed in front of and afterwards on its inner side. Extending into the thigh, the trunk is distributed to the hamstring muscles by means of two sets of branches. Just below the level of the ischial tuberosity an upper set of nerves passes inwards to enter the upper part of the semi-tendinosus and the ischial head of the biceps. Lower down in the thigh the remaining portion of the nerve separates off from the great sciatic (tibial) trunk and supplies branches to the semi-membranosus, the lower part of the semi-tendinosus, and the adductor magnus.

Articular branches for the hip-joint arise from the nerve to the quadratus femoris, and often directly from the front of the great sciatic (tibial) nerve near its origin. They enter the back of the capsule of the joint in the region of the buttock.

The *posterior branches* are: (*a*) muscular branches, viz. a nerve to the pyriformis, the superior gluteal nerve, the inferior gluteal nerve, and a nerve to the short head of the biceps; (*b*) articular branches (to the knee-joint).

These nerves all arise from the posterior aspect of those roots of the sacral plexus, which are associated with the origin of the peroneal nerve.

The **nerve to the pyriformis muscle** may be double. It arises from the back of the second, or first and second sacral nerves, and at once enters the anterior surface of the muscle.

The **superior gluteal nerve** (n. glutæus superior) arises from the back of the fourth and fifth lumbar and first sacral nerves, and is directed backwards and outwards into the buttock, above the pyriformis muscle, along with the gluteal artery. Under cover of the gluteus maximus and gluteus medius, it extends outwards over the gluteus minimus, along with the inferior part of the deep gluteal artery, to the under surface of the tensor vaginæ femoris, in which it ends. On its way it supplies branches to the gluteus medius and gluteus minimus.

The **inferior gluteal nerve** (n. glutæus inferior) arises from the back of the fifth lumbar and first two sacral nerves. It appears in the buttock at the lower border of the pyriformis muscle, superficial to the great sciatic nerve, and at once breaks up into a number of branches for the supply of the gluteus maximus. In its course in the buttock it is closely associated with the small sciatic nerve. Its origin is sometimes combined with that of the following nerve.

The **nerve to the short head of the biceps** springs from the outer side of the

great sciatic (peroneal) trunk in the upper part of the thigh. When traced to its origin, it is found to arise (sometimes in combination with the inferior gluteal nerve) from the fifth lumbar and first two sacral nerves. In its course it is closely applied to the outer side of the peroneal nerve, from which it separates in the middle third of the thigh, usually in combination with the articular branches of that nerve for the knee-joint. In some cases it has an independent course in the thigh, and it may be associated in the buttock with the inferior gluteal nerve.

An **articular branch** for the outer side and front of the knee-joint generally arises from the great sciatic or peroneal nerve in common with the nerve to the short head of the biceps. When traced up to the plexus, it is found to arise from the back of the fourth and fifth lumbar and first sacral nerves. It passes through the upper part of the popliteal space concealed by the biceps muscle, and separates into upper and lower branches, which accompany the upper and lower external articular arteries to the outer side of the knee-joint.

Terminal Branches.—The **peroneal** (external popliteal) and **tibial** (internal popliteal) **nerves** are the two main trunks resulting from the combination of the posterior and anterior cords respectively of the sacral plexus. The peroneal nerve is homologous with the musculo-spiral nerve in the upper limb; the tibial nerve represents a medio-ulnar trunk; and, as already stated, the two nerves, constituting the great sciatic nerve, are enveloped in a common sheath for a variable distance before pursuing an independent course in the leg.

Peroneal Nerve.

The **peroneal** or **external popliteal nerve** (n. peronæus communis) arises from the back of the sacral plexus from the fourth and fifth lumbar and first two sacral nerves. Incorporated with the great sciatic nerve in the buttock and upper half of the thigh, it passes downwards from the bifurcation of that nerve through the popliteal space, to its termination at a point about an inch below the head of the fibula. It is concealed at first by the biceps muscle. Following the tendon of that muscle, it passes obliquely through the upper and outer part of the popliteal space and over the outer head of the gastrocnemius muscle to the back of the head of the fibula. In the lower part of its course and at its termination it is directly beneath the deep fascia.

Collateral Branches.—These are divided into two sets: (*a*) Nerves arising from the roots or trunk of the nerve while it is in combination with the tibial nerve in the great sciatic trunk. These have been already described, viz. a **muscular branch** to the short head of the biceps, and an **articular branch** to the knee-joint. (*b*) Nerves arising in the popliteal space. These are **cutaneous branches**, viz. a sural branch and the peroneal communicating.

The **sural branch** (n. cutaneus suræ lateralis) is irregular in size and distribution, and may be represented by two or more branches (Fig. 507, p. 645). Arising from the peroneal nerve in the popliteal space, often in common with the succeeding nerve, it pierces the deep fascia over the outer head of the gastrocnemius, and is distributed to the skin on the outer aspect of the back of the leg in the upper two-thirds. The extent of its distribution varies with that of the small sciatic and external saphenous nerves.

The **peroneal communicating nerve** (r. anastomoticus peronæus, r. communicans fibularis), arising in the popliteal space, passes over the outer head of the gastrocnemius beneath the deep fascia to the middle third of the leg, where it assists in forming the external saphenous nerve by its union with the tibial communicating branch of the tibial nerve. In many cases the two branches do not unite. In such cases the peroneal communicating nerve may be limited in its distribution to the skin of the outer side of the leg, heel, and ankle, or it may be distributed to the area usually supplied by the external saphenous nerve.

Terminal Branches.—The terminal branches of the peroneal nerve are recurrent tibial, anterior tibial, and musculo-cutaneous. They arise just below the head of the fibula, and are directed forwards, diverging in their course, beneath the peroneus longus muscle.

The **recurrent tibial nerve** is the smallest branch. Passing forwards beneath

the origin of the peroneus longus and the extensor longus digitorum muscles, it divides below the outer tuberosity of the tibia into branches which supply the upper fibres of the tibialis anticus muscle, the tibio-fibular articulation, and the knee-joint.

Anterior Tibial Nerve.

The **anterior tibial nerve** (n. peronæus profundus) passes downwards and inwards, beneath the peroneus longus, extensor longus digitorum, and extensor proprius hallucis muscles, to the front of the leg. In its course down the leg it is deeply placed upon the interosseous membrane and the lower part of the tibia, in company with the anterior tibial artery. At the ankle it lies beneath the anterior annular ligament and the tendon of the extensor proprius hallucis, and crossing over the ankle-joint, it divides on the dorsum of the foot into its terminal branches.

1. **Collateral Branches** (in the leg).—These are given off to the muscles between which the anterior tibial nerve passes: tibialis anticus, extensor proprius hallucis, extensor longus digitorum, and peroneus tertius. A fine articular branch supplies the ankle-joint.

2. **Terminal Branches** (on the foot).—The terminal branches are internal and external. The **internal branch** passes along the dorsum of the foot on the outer side of the dorsalis pedis artery to the first interosseous space, where it divides into two dorsal digital branches for the supply of the skin of the outer side of the great toe and the inner side of the second toe. Each of these branches communicates with branches of the musculo-cutaneous nerve. It gives off one or two *dorsal interosseous branches*, which supply the inner tarso-metatarsal and metatarso-phalangeal articulations, and also enter the first dorsal interosseous muscle.

The **external branch** passes outwards over the tarsus beneath the extensor brevis digitorum, and ends in a gangliform enlargement (similar to the gangliform enlargement on the posterior interosseous nerve at the back of the wrist). From this enlargement muscular branches arise for the supply of the extensor brevis digitorum, along with branches for the tarsal, tarso-metatarsal, and metatarso-phalangeal articulations. Its *dorsal interosseous branches* may be as many as four in number. Of these the outer two, extremely small, may only reach the tarso-metatarsal articulations. The inner two are fine branches, which, besides supplying the articulations, may give branches to the second and third dorsal interosseous muscles.

The branches from the anterior tibial nerve to the interosseous muscles are probably sensory, the motor supply of these muscles being certainly derived from the external plantar nerve.

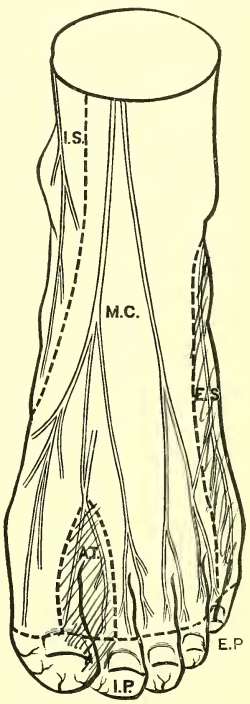


Fig. 508.—Distribution of Cutaneous Nerves on the Dorsum of the Foot.

I.S, Internal saphenous nerve; M.C, Musculo-cutaneous nerve; A.T, Anterior tibial nerve; E.S, External saphenous nerve. The extremities of the toes are supplied by the plantar nerves (I.P, E.P).

Musculo-Cutaneous Nerve.

The **musculo-cutaneous nerve** (n. peronæus superficialis), the last of the branches of the peroneal nerve, passes below the head of the fibula and beneath the upper fibres of the peroneus longus muscle. Lying in a sheath in the intermuscular septum, between the peronei externally and the extensor longus digitorum internally, it proceeds downwards in front of the fibula to the lower third of the leg, where it pierces the deep fascia in two branches, internal and external.

Its branches are: (1) collateral muscular branches distributed to the peroneus longus and peroneus brevis, as the nerve lies in relation to these muscles; (2) terminal cutaneous branches, internal and external.

The **internal terminal branch** courses downwards over the anterior annular liga-

ment of the ankle, and after supplying offsets to the lower third of the leg and dorsum of the foot, divides into three branches. (1) The internal branch supplies the skin of the dorsum of the foot and the inner side of the great toe, and communicates with the internal saphenous nerve. (2) The intermediate branch passes to the interval between the great toe and the second, and divides into two branches which communicate with the internal branch of the anterior tibial nerve. (3) The external branch passes to the interval between the second and third toes, and divides into two digital branches to supply the adjacent sides of these toes.

The **external terminal branch** of the nerve descends over the anterior annular ligament, and after supplying branches to the lower part of the leg and the dorsum of the foot, divides into two parts, internal and external, which, passing to the intervals between the third and fourth, and fourth and fifth toes respectively, divide into dorsal digital branches for the adjacent sides of these toes. These branches communicate with offsets of the external saphenous nerve.

The arrangement of the cutaneous branches of the musculo-cutaneous is liable to considerable variation. The outer division of the nerve may be increased in size, and may supply the nerve to the adjacent sides of the second and third toes; or in other cases, it may be reduced in size, in which case the external saphenous nerve takes its place on the dorsum of the foot, often supplying as many as two and a half toes on the outer side.

The cutaneous nerves on the dorsum of the toes from the anterior tibial and musculo-cutaneous nerves are much smaller than the corresponding plantar digital nerves. They are reinforced on the dorsum of the terminal phalanges by twigs from the plantar nerves, which supply the tips of the toes and the nails.

Tibial Nerve.

The **tibial** or **internal popliteal nerve** (n. tibialis) arises from the front of the sacral plexus, usually from the fourth and fifth lumbar and first three sacral nerves (Fig. 511, p. 656). It is incorporated in the great sciatic trunk in the buttock and upper part of the thigh. At the bifurcation of the great sciatic nerve it passes onwards through the popliteal space and the back of the leg. The part of the nerve from its origin from the plexus or the bifurcation of the great sciatic nerve to the lower border of the popliteus muscle, is sometimes called **internal popliteal**; the part of the nerve in the back of the leg being then designated **posterior tibial.** The course of the nerve through the buttock and thigh has already been described (p. 648). In the popliteal space it is concealed at first by the semi-membranosus and other hamstring muscles. It crosses the popliteal vessels from without inwards, and is thereafter found upon the popliteus muscle, under cover of the gastrocnemius and plantaris. In the back of the leg, from the lower border of the popliteus muscle to the ankle, the tibial (or posterior tibial) nerve lies on the tibialis posticus muscle and the tibia, and, along with the posterior tibial vessels, occupies a sheath in the intermuscular septum separating the superficial and deep muscles of the back of the leg. In the upper part of the leg the nerve is internal to the vessels, but, crossing over them, it lies on their outer side in the lower portion of its course. It terminates beneath the internal annular ligament by dividing into the external and internal plantar nerves.

The **collateral branches** may be divided into three series arising respectively in the region of the thigh, the popliteal space, and the back of the leg:—

(a) *Branches arising from the Roots or Trunk of the Nerve while it is incorporated with the Great Sciatic Nerve.*—These have been already described, viz. **muscular branches** to the quadratus femoris, gemelli, obturator internus, and the hamstring muscles, and an **articular branch** to the hip-joint (Fig. 511, p. 656).

(b) *Branches arising in the Popliteal Space above the Knee-Joint.*—These are in three sets—articular, muscular, cutaneous.

1. The **articular branches** are slender nerves, variable in number. There are usually two, an *azygos* branch which pierces the posterior ligament of the knee-joint, and an *internal* branch, a long fine nerve which, crossing the popliteal vessels, descends on the inner side of the space to accompany the lower internal articular artery to the knee-joint. In its course it gives off a branch, often absent, which accompanies the upper internal articular artery.

2. The **muscular branches** are five in number. Nerves for the two heads of the gastrocnemius, and the plantaris enter these muscles at the borders of the popliteal

space. A nerve for the soleus enters the superficial surface of the muscle. A nerve for the popliteus muscle passes over the surface of that muscle, and after winding round its lower border, supplies it on its deep (anterior) surface. As this nerve passes beneath the popliteus it supplies branches to the tibialis posticus muscle, an interosseous branch for the interosseous membrane, which can be traced as far as the lower tibio-fibular articulation, an articular branch for the upper tibio-fibular joint, and a medullary branch for the shaft of the tibia.

3. The **cutaneous branch** is the **tibial communicating nerve** (n. communicans tibialis, n. cutaneus suræ medialis). This nerve passes from the popliteal space in the groove between the two heads of the gastrocnemius muscle, and afterwards lies upon the tendo achillis. It pierces the deep fascia in the middle third of the back of the leg, and is joined immediately afterwards by the peroneal communicating nerve from the peroneal nerve. From their union the **external** or **short saphenous nerve** results, which reaches the foot, winding round the back of the external malleolus along with the external saphenous vein. The external saphenous nerve supplies cutaneous branches to the outer side and back of the lower third of the leg, the ankle and heel, and the outer side of the foot and little toe, as well as articular branches to the ankle and tarsal joints.

The external saphenous nerve communicates on the foot with the musculo-cutaneous nerve, and its size varies with the size of that nerve. It may extend on to the dorsum of the foot for a considerable distance, and may either reinforce or replace the branches of the musculo-cutaneous nerve to the intervals between the fourth and fifth and the third and fourth toes. The mode of formation of the external saphenous nerve is very variable. The usual arrangement is that described. Frequently the peroneal and tibial communicating nerves do not unite, and in such cases the more usual arrangement is for the tibial communicating nerve to form alone the external saphenous nerve, the peroneal communicating nerve extending only to the ankle and heel. It is less usual for the peroneal communicating nerve to form alone the external saphenous nerve, the tibial communicating nerve in these cases ending at the heel.

(c) *Branches arising in the Back of the Leg below the Knee-Joint.*—These branches are mainly muscular and cutaneous.

The **muscular branches** are four in number, comprising nerves to the soleus (entering its deep surface) and tibialis posticus, often arising by a common trunk, and nerves to the flexor longus digitorum and flexor longus hallucis, the latter generally accompanying the peroneal artery for some distance.

The **cutaneous branch** is the **internal calcanean nerve** (rr. calcanei mediales), which pierces the internal annular ligament, and is distributed to the skin of the heel and back part of the sole of the foot.

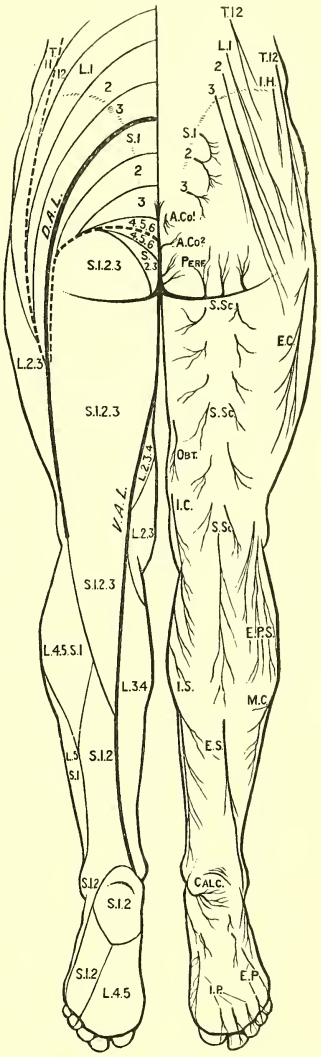


FIG. 509.—DISTRIBUTION OF CUTANEOUS NERVES ON THE BACK OF THE LOWER LIMB.

On the one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

L.1, 2, 3, S.1, 2, 3, Posterior primary divisions of lumbar and sacral nerves; I.H, Ilio-hypogastric; T.12, Lateral and posterior branches of last thoracic nerve; A.Co¹, Posterior sacro-coccygeal nerve; A.Co², Anterior sacro-coccygeal nerve; PERF, Perforating cutaneous nerve; S.Sc, Small sciatic; E.C, External cutaneous; OBT, Obturator; I.C, Internal cutaneous; E.P.S, Sural branches of peroneal; I.S, Internal saphenous; E.S, External saphenous; M.C, Musculo-cutaneous; CALC, Calcanean branch of posterior tibial; I.P, Internal plantar; E.P, External plantar nerve.

On the other side a schematic representation is given of the areas supplied by the above nerves, the figures indicating the spinal origin of the branches of distribution to each area.

In addition a medullary nerve to the fibula, and a small articular branch to the ankle-joint, are supplied by the posterior tibial nerve.

The **terminal branches of the tibial nerve** are the internal and external plantar nerves.

Internal Plantar Nerve.

The **internal plantar nerve** (n. plantaris medialis) is homologous with the median nerve in the hand (Fig. 510, p. 654). It is rather larger than the external plantar. It courses forwards in the sole of the foot beneath the internal annular ligament and abductor hallucis to the interval between that muscle and the flexor brevis digitorum, in company with the internal plantar artery.

The **collateral branches** are muscular, cutaneous, and articular. The *muscular* branches supply the abductor hallucis and the flexor brevis digitorum. The plantar *cutaneous* branches are small twigs which pierce the plantar fascia in the interval between these muscles to supply the inner part of the sole of the foot. The *articular* branches are minute twigs which supply the inner tarsal and tarso-metatarsal articulations.

The **terminal branches** are four in number, and may be designated first, second, third, and fourth, from within outwards.

The **first** (most internal) branch separates from the nerve before the others, and pierces the plantar fascia behind the ball of the great toe. It supplies a muscular branch to the flexor brevis hallucis, and cutaneous branches to the inner side of the foot and ball of the great toe. It terminates as the plantar digital nerve for the inner side of the great toe.

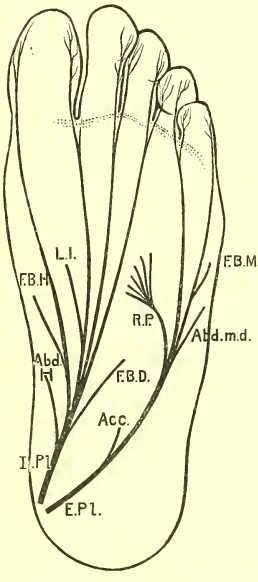


Fig. 510.—Scheme of Distribution of the Plantar Nerves.

I. Pl, Internal plantar nerve, and its cutaneous and muscular branches; F.B.D, Flexor brevis digitorum; Abd.H, Abductor hallucis; F.B.H, Flexor brevis hallucis; L.I, First lumbricalis; E.Pl, External plantar nerve, and its cutaneous and muscular branches; Acc, Accessorius; Abd.m.d, Abductor minimi digiti; F.B.M.D, Flexor brevis minimi digiti; R.P, Ramus profundus.

The **second branch** arises along with the third and fourth; after supplying a branch to the first lumbrical muscle, it becomes superficial in the interval between the first and second toes, and terminates by dividing into two collateral digital nerves for the supply of the adjacent sides of these toes.

The **third** and **fourth branches** are entirely cutaneous in their distribution. They become superficial in the intervals between the second and third and the third and fourth toes respectively, and there divide into collateral digital branches for the supply of the adjacent sides of these toes.

The **plantar digital nerves** supply the whole length of the toes on the plantar aspect, and, in relation to the terminal phalanges, furnish minute dorsal offsets for the supply of the nails and tips of the toes on their dorsal surface. The internal plantar nerve thus supplies the skin of the three and a half inner toes in the sole of the foot; and four muscles:—the abductor hallucis and flexor brevis digitorum, the flexor brevis hallucis, and the first lumbrical muscle.

External Plantar Nerve.

The **external plantar nerve** (n. plantaris lateralis) is homologous with the ulnar nerve in the hand. From its origin beneath the internal annular ligament it extends forwards and outwards in the sole, in company with the external plantar artery, between the flexor brevis digitorum and accessorius muscles, towards the head of the fifth metatarsal bone. Here it terminates by dividing into superficial and deep branches.

Collateral Branches.—*Muscular branches* are given off from the undivided nerve to the accessorius and abductor minimi digiti muscles. *Cutaneous branches* pierce the plantar fascia at intervals along the line of the intermuscular septum, between the flexor brevis digitorum and abductor minimi digiti.

Terminal Branches.—The **superficial branch** (r. superficialis) is mainly cutaneous.

Passing forwards between the flexor brevis digitorum and abductor minimi digiti, it divides into external and internal parts.

The *external branch*, after supplying the flexor brevis minimi digiti muscle, and sometimes one or both interossei of the fourth space, becomes superficial behind the ball of the little toe, and supplies cutaneous twigs to the sole of the foot and ball of the toe. It terminates as the digital branch for the outer side of the little toe.

The *internal branch* passes forwards to the interval between the fourth and fifth toes, where it becomes cutaneous, and divides into two collateral digital branches for the supply of the adjacent sides of these toes. It communicates with the fourth terminal branch of the internal plantar nerve.

The **deep branch** (r. profundus) of the external plantar nerve, passing deeply along with the external plantar artery, extends inwards towards the great toe, beneath the accessorius and adductor obliquus hallucis. It gives off *articular branches* to the tarsal and tarso-metatarsal articulations, and *muscular branches* to the interossei of each space (except in some cases the muscles of the fourth space): to the adductor obliquus and adductor transversus hallucis, and the outer three lumbrical muscles. These nerves enter the deep surface of the muscles, that to the second lumbrical reaching its muscle after passing forwards beneath the adductor transversus hallucis.

THE PUDENDAL PLEXUS.

The pudendal plexus constitutes the third and last subdivision of the lumbo-sacral plexus. It is composed for the most part of the spinal nerves below those which form the sacral plexus; but, as already stated, there is no distinct point of separation between the two plexuses. On the contrary, there is considerable overlapping, so that two and sometimes three of the principal nerves derived from the pudendal plexus have their origin in common with nerves of the sacral plexus.

The plexus is formed by fibres from the anterior primary divisions of the first three sacral nerves, and by the whole of the anterior primary divisions of the fourth and fifth sacral and coccygeal nerves. The size of the nerves diminishes rapidly from the first sacral to the coccygeal, which is extremely slender.

Position and Constitution.—The plexus is formed on the back wall of the pelvis. Of the nerves forming it, the upper ones emerge from the anterior sacral foramina; the fifth sacral nerve appears between the last sacral and first coccygeal vertebra; and the coccygeal nerve appears below the transverse process of that vertebra. The nerves of distribution derived from the plexus are the following:—

1. Visceral branches.
2. Small sciatic nerve.
3. Perforating cutaneous nerve.
4. Pudic nerve.
5. Muscular branches.
6. Sacro-coccygeal nerve.

Omitting the visceral branches, all the nerves are distributed to the perineum. Only two, the small sciatic and perforating cutaneous nerves, send branches to the lower limb.

Visceral Branches.—Like the other spinal nerves, the fourth and fifth sacral and coccygeal nerves are provided with fine *gray rami communicantes* from the sacral gangliated cord, which joins them after a short course on the front of the sacrum. The third (along with the second or fourth) sacral nerve in addition sends a considerable *white ramus communicans* or **visceral branch** inwards to the pelvic plexus and viscera.

Small Sciatic Nerve (n. cutaneus femoris posterior).—This nerve is complex both in origin and distribution (Fig. 511, p. 656). Springing from the junction of the sacral and pudendal plexuses, it is derived from the first three or second and third sacral nerves. It is distributed to the lower limb and perineum, and is associated with other nerves belonging to both regions. It arises from the back of the roots of the sacral plexus in the pelvis. Its higher roots from the first and second sacral nerves are intimately associated with the origin of the inferior gluteal nerve; its lowest root from the third sacral nerve is associated with the origins of the perforating cutaneous or pudic nerve. It enters the buttock through the great sciatic notch below the pyriformis, along with the sciatic artery and inferior gluteal

nerve. Proceeding downwards behind the great sciatic nerve, it enters the thigh at the lower border of the gluteus maximus muscle, where it gives off considerable branches. Becoming gradually smaller as it courses downwards over the hamstring

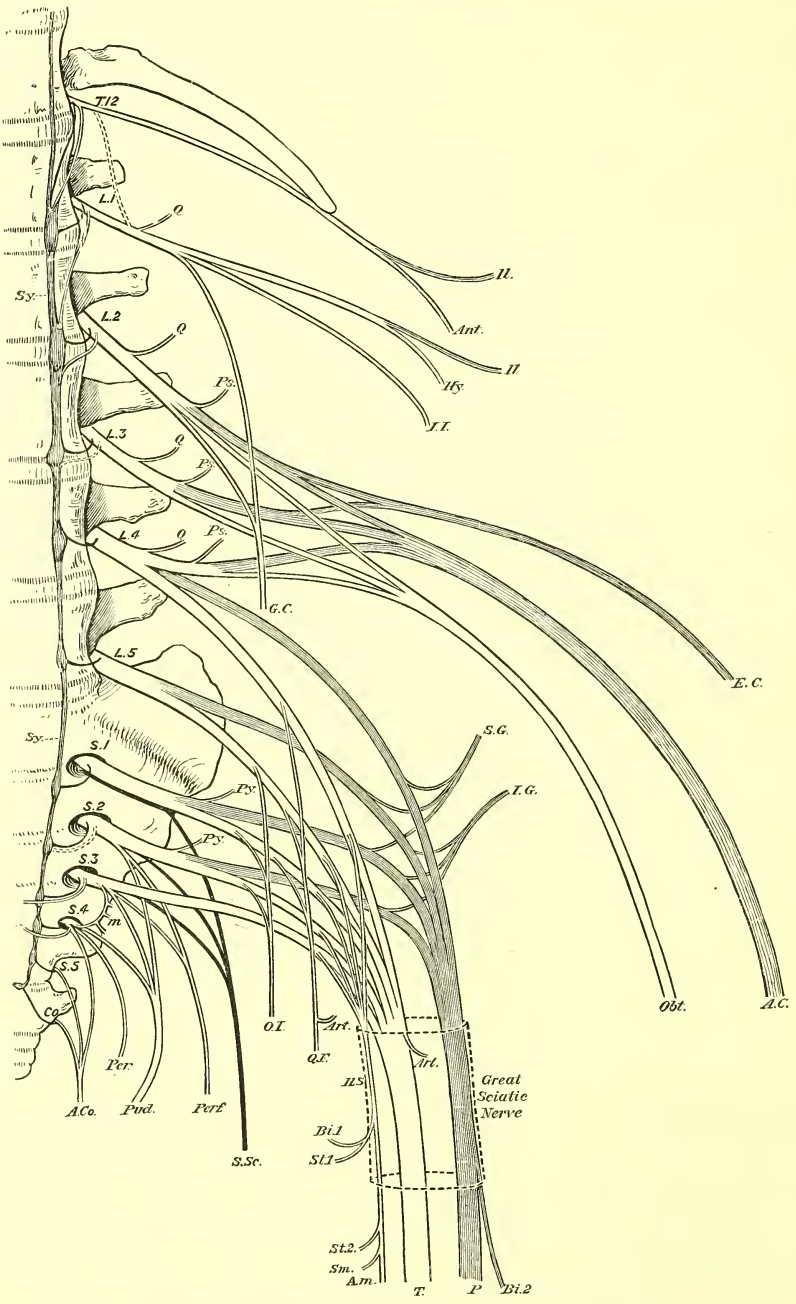


FIG. 511.—NERVES OF THE LUMBO-SACRAL PLEXUS.

Sy, Sympathetic cord ; T.12, L.1, 2, 3, 4, 5, S.1, 2, 3, 4, 5, Co, Anterior primary divisions of the last thoracic, the lumbar, sacral, and coccygeal nerves ; Q, Nerves to quadratus lumborum ; Ps, Nerves to psoas muscle ; G.C, Genito-crural nerve ; Il, Iliac branches of last thoracic and ilio-hypogastric nerves ; Hy, Hypograstic branch of ilio-hypogastric nerve ; I.I, Ilio-inguinal nerve ; E.C, External cutaneous nerve ; A.C, Anterior crural nerve ; Obt, Obturator nerve ; Py, Nerves to pyriformis muscle ; O.I, Nerve to obturator internus ; Q.F, Nerve to quadratus femoris muscle ; Art, Articular branch ; S.G, Superior gluteal nerve ; I.G. Inferior gluteal nerve ; P, Peroneal nerve ; Bi.2, Nerve to short head of biceps muscle ; T, Tibial nerve ; Art, Articular branch ; H.S, Nerve to the hamstring muscles ; Bi.1, Nerves to biceps (long head), and St.1, to semi-tendinosus ; St.2, Semi-tendinosus ; Sm, Semi-membranosus ; A.m, Adductor magnus ; S.Sc, Small sciatic nerve ; Perf, Perforating cutaneous nerve ; Pud, Pudic nerve ; M, Muscular branches ; Per, Perineal branch of fourth sacral ; A.Co, Anterior sacro-coccygeal nerve.

muscles to the popliteal space, it finally pierces the popliteal fascia in one or more cutaneous branches, which supply the skin over the calf of the leg for a variable distance (Fig. 509, p. 653).

Branches.—The small sciatic is a purely cutaneous nerve. It supplies branches to the perineum, buttock, thigh, and leg.

The **perineal branch** (rr. perinæales; inferior pudendal nerve; long scrotal nerve) arises from the small sciatic nerve at the lower border of the gluteus maximus muscle (Fig. 512, p. 658). It sweeps inwards towards the perineum, lying on the origin of the hamstring muscles below the ischial tuberosity, and becomes subcutaneous after passing over the pubic arch. Its terminal branches supply the skin of the scrotum and root of the penis, or in the female the labium majus and clitoris, some of them being directed backwards towards the anus and central point of the perineum. They communicate with the inferior hæmorrhoidal and perineal branches of the pudic nerve, and with the ilio-inguinal nerve. In its course to the perineum the nerve gives off *collateral branches* to the skin of the upper and inner part of the thigh.

The **gluteal branches** (rr. clunium inferiores) are large and numerous (Fig. 509, p. 653). They arise from the small sciatic nerve beneath the gluteus maximus, and become subcutaneous by piercing the fascia lata at different points along its lower border. They supply the skin of the lower half of the buttock. The outermost branches, reaching to the back of the great trochanter, overlap the terminal filaments of the gluteal branches of the external cutaneous nerve, and the posterior primary divisions of the first three lumbar nerves. The innermost branches, which may pierce the great sacro-sciatic ligament, reach nearly to the coccyx, and are co-terminous in their distribution with the branches of the perforating cutaneous nerve, which they reinforce and not infrequently replace.

The **femoral branches** are divisible into two sets—*internal* and *external*. They pierce the fascia lata of the thigh at intervals, and supply the skin of the back of the thigh on its inner and outer sides respectively.

The **sural branches** are two or more slender nerves which pierce the fascia over the popliteal space, and are distributed for a variable extent to the skin of the back of the leg. They may stop short over the popliteal space, or may extend as far as the ankle. Usually they innervate the skin as far as the middle of the calf. They communicate with the external saphenous nerve.

In cases where the great sciatic nerve is naturally divided at its origin into tibial (internal popliteal) and peroneal (external popliteal) nerves (*e.g.* by the pyriformis muscle), the small sciatic nerve is also separated into two parts: a **dorsal part**, associated with the peroneal nerve and arising in common with the lower roots of the inferior gluteal nerve (usually from the first and second sacral nerves), and comprising the gluteal and external femoral branches; and a **ventral part**, associated with the tibial nerve and arising usually from the second and third sacral nerves, along with the perforating cutaneous and pudic nerves, and comprising the perineal and internal femoral branches.

Perforating Cutaneous Nerve (n. perforans ligamenti tuberoso-sacri (Schwalbe), n. cutaneus clunium inferior medialis (Eisler)).—This nerve arises from the back of the second and third sacral nerves (Fig. 512, p. 658). At its origin it is associated with the lower roots of the small sciatic nerve. Passing downwards it pierces the great sacro-sciatic ligament, along with the coccygeal branch of the sciatic artery; and after winding round the lower border of the gluteus maximus muscle, or in some cases piercing its lower fibres, it becomes subcutaneous a little distance from the coccyx, and supplies the skin over the lower part of the buttock and the inner part of the fold of the nates.

The perforating cutaneous nerve is not always present. In a minority of cases it is associated at its origin with the pudic nerve. When absent as a separate nerve, its place is taken by (1) gluteal branches of the small sciatic nerve, or (2) a branch from the pudic nerve, or (3) a small nerve (n. perforans coccygeus major, Eisler), arising separately from the back of the third and fourth sacral nerves.

Muscular Branches.—Between the third and fourth sacral nerves (occasionally reinforced by the second, Eisler) a plexiform loop is formed, from which muscular nerves are given off to the levator ani (supplying the muscle on its pelvic surface), coccygeus, and external sphincter. The nerve to the external sphincter

(*perineal branch of fourth sacral*) pierces the great sacro-sciatic ligament and the coccygeus muscle, to which it gives offsets, and appears in the ischio-rectal fossa between the gluteus maximus and the external sphincter. Besides supplying the posterior fibres of the external sphincter, it distributes cutaneous offsets to the skin of the ischio-rectal fossa and the fold of the nates behind the anus. This nerve replaces in some instances the perforating cutaneous nerve.

Anterior Sacro-coccygeal Nerves (nn. ano-coccygei).—By the union of the remaining part of the fourth with the fifth sacral and coccygeal nerves, the so-called **coccygeal plexus** is formed. A fine descending branch of the fourth sacral nerve passes over or through the great sacro-sciatic ligament, to join the fifth sacral nerve. This fifth sacral nerve, joined by the descending branch of the fourth, descends alongside the coccyx and is again joined by the coccygeal nerve, so that a plexiform cord results, homologous with the inferior caudal trunk of tailed animals. Fine twigs arise from it, which pierce the sacro-sciatic ligament and supply the skin in the neighbourhood of the coccyx, internal to the perforating cutaneous nerves and behind the anus.

The Pudic Nerve.

The **pudic nerve** (n. pudendus) is the principal nerve for the supply of the perineum. It arises in the pelvis usually by three roots from the second, third, and

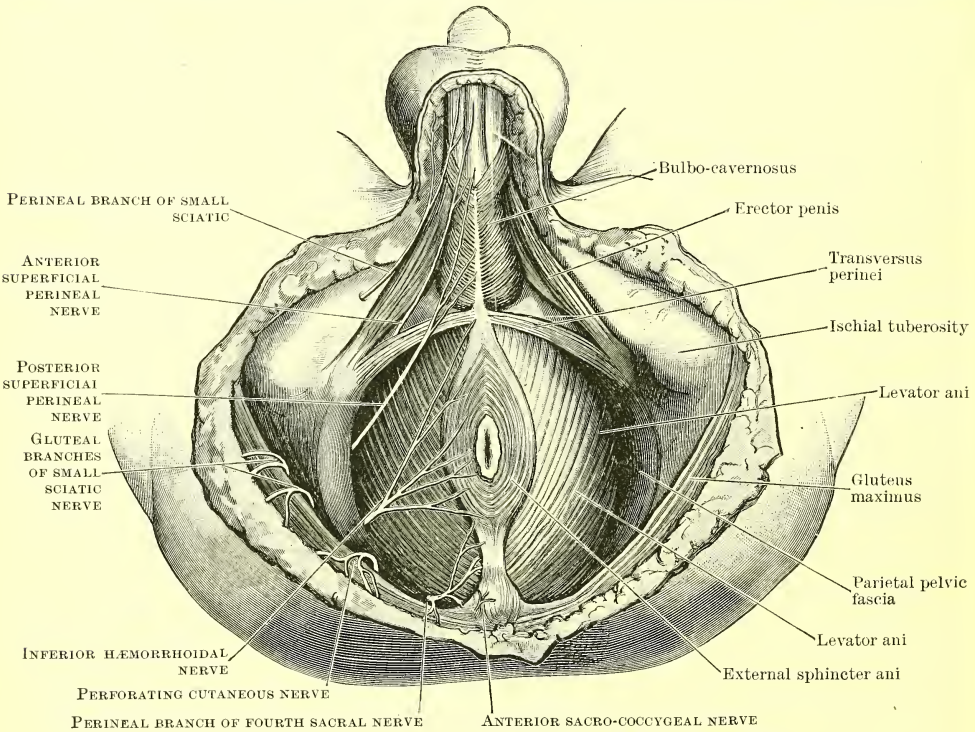


Fig. 512.—The Muscles and Nerves of the Male Perineum.

fourth sacral nerves (Fig. 511, p. 656). (Frequently one of its branches, the inferior hæmorrhoidal nerve, arises independently from the third and fourth sacral nerves). The nerve passes to the buttock through the great sacro-sciatic foramen below the great sciatic nerve, and lies on the lesser sacro-sciatic ligament, or the spine of the ischium, internal to the internal pudic artery. It enters the perineum along with the pudic artery through the small sacro-sciatic foramen. In the perineum it is deeply placed in the outer wall of the ischio-rectal fossa, enclosed in a special sheath derived from the parietal pelvic fascia covering the inner surface of the obturator internus muscle. At the anterior limit of the ischio-rectal fossa, the nerve approaches the surface and divides at the base of the triangular ligament into its terminal branches, the perineal nerve and the dorsal nerve of the penis.

The branches of the pudic nerve are essentially the same in the two sexes. As a rule no branches are given off till the nerve enters the perineum, but sometimes the inferior hæmorrhoidal nerve has an independent origin from the plexus, merely accompanying the pudic nerve in the first part of its course; and in exceptional cases the perforating cutaneous nerve of the buttock is a branch of the pudic nerve.

The **inferior hæmorrhoidal nerve** (n. hæmorrhoidalis inferior) arises from the pudic nerve under cover of the gluteus maximus, at the posterior part of the ischio-rectal fossa. In cases in which it has an independent origin from the plexus, it arises from the third and fourth sacral nerves. It crosses the ischio-rectal fossa in company with the inferior hæmorrhoidal vessels, and separates into numerous branches—muscular, cutaneous, and communicating.

The **muscular branches** end in the external sphincter ani muscle. The **cutaneous branches** supply the skin around the anus. The **communicating branches** connect the inferior hæmorrhoidal with three other nerves—the perineal branches of the small sciatic, pudic, and fourth sacral nerves.

The **perineal nerve** (n. perineus), one of the two terminal branches of the pudic nerve, arises near the base of the triangular ligament. It almost immediately divides into two parts, superficial and deep.

The **superficial part** is purely cutaneous and consists of two nerves, the posterior

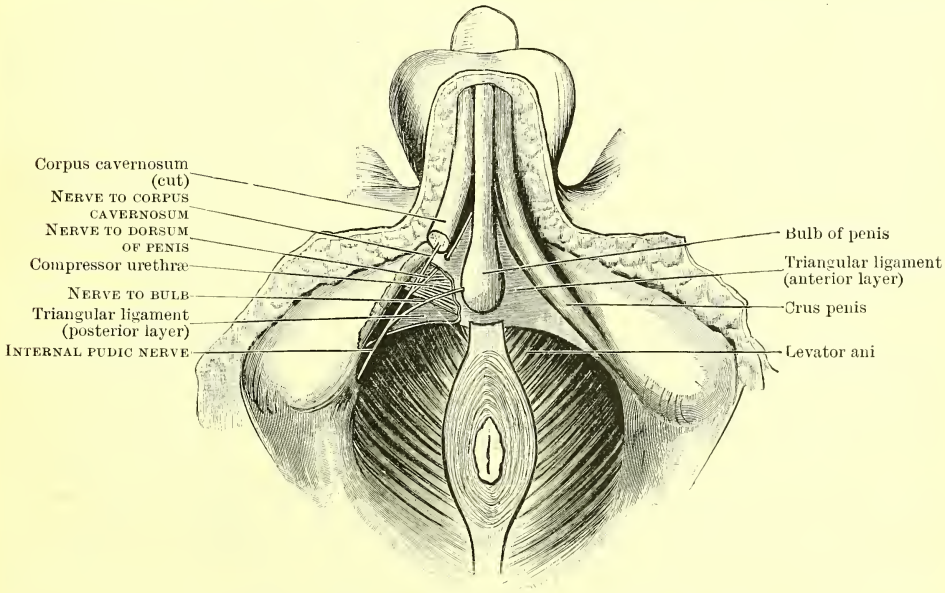


Fig. 513.—The Triangular Ligament of the Perineum.

or external and the anterior or internal superficial perineal nerves, which pass, along with the superficial perineal vessels, to the anterior part of the perineum. The **posterior or external superficial perineal nerve**, at the anterior limit of the ischio-rectal fossa, usually passes over the base of the triangular ligament and over the transversus perinei muscle. The **anterior or internal superficial perineal nerve**, lying more deeply, pierces the base of the triangular ligament and goes underneath or through the transversus perinei muscle. Becoming superficial in the anterior (urethral) triangle of the perineum, they are distributed to the skin of the scrotum (or labium majus), and communicate with the perineal branch of the small sciatic nerve and with the inferior hæmorrhoidal nerve.

The **deep part** of the perineal nerve is mainly but not entirely muscular. Coursing forwards through the anterior part of the ischio-rectal fossa, it passes between the two layers of the triangular ligament towards the urethra. It supplies muscular branches to the anterior parts of the levator ani and external sphincter, to the transversus perinei, erector penis (or clitoridis), bulbo-cavernosus (ejaculator urinæ or sphincter vaginæ), and compressor urethræ. It terminates as the nerve to the bulb, which, piercing the triangular ligament, enters the bulb of the urethra

and supplies the erectile tissue of the bulb and corpus spongiosum, as well as the mucous membrane of the urethra as far as the glans penis (or clitoridis).

The **dorsal nerve of the penis**, the other terminal branch of the pudic nerve, accompanies the internal pudic artery beneath the superficial layer of the triangular ligament. It passes forward close to the pubic arch, lying beneath the crus and erector penis (or clitoridis), and triangular ligament, and upon the compressor urethræ muscle; piercing the triangular ligament near its apex, at the outer side of the dorsal artery of the penis (or clitoris), it passes on to the dorsum of the penis or clitoris, to which it is distributed in its distal two-thirds, sending branches round the sides of the organ to reach its under surface. In the female the nerve is much smaller than in the male. The dorsal nerve of the penis supplies one branch, the **nerve to the corpus cavernosum**, as it lies beneath the triangular ligament. This is a slender nerve, which, piercing the triangular ligament, supplies the erectile tissue of the crus and corpus cavernosum.

Morphology of the Pudendal Plexus.—The structures occupying the perineum are placed in the ventral axis of the body, and comprise from before backwards, the penis and scrotum, or mons Veneris and vulva, the central point of the perineum, the anus and ischio-rectal fossa, and the coccyx. They are placed on the mesial side of the attachment of the lower limbs—the penis or mons Veneris in relation to the preaxial border; the coccyx in relation to the postaxial border of the limb.

The nerves of the perineum, thus reaching the ventral axis of the trunk, are homologous with the anterior (ventral) terminations of other nerves. They are separated into two series. Mainly supplied through the pudendal plexus by the last four sacral and the coccygeal nerves, the perineum is also innervated to a minor extent by the first lumbar nerve through the ilio-inguinal nerve, which reaches the root of the penis and the scrotum. The region is thus supplied by two series of widely separated nerves, which have their meeting-place on the dorsum and side of the penis and scrotum. This junction of the ilio-inguinal and pudendal nerves constitutes the beginning of the **ventral axial area or line**, which extends peripherally along the inner side of the lower limb. Apart from this break in their distribution, a definite numerical order may be followed in the arrangement of the perineal nerves. The higher parts of the perineum are innervated by the higher spinal nerves; the lower parts, by the lower nerves. This is best exemplified in the distribution of the cutaneous nerves. The base of the penis and scrotum (or mons Veneris) is supplied by the first lumbar nerve (ilio-inguinal). The dorsal nerve of the penis (or clitoris), when traced back to the pudendal plexus, is found to come from the second, and to a less extent from the third sacral nerves; the scrotal nerves (perineal branches of the pudic and small sciatic) similarly arise from the third, and to a less extent from the second sacral nerves; the skin of the ischio-rectal fossa and anus is innervated by the inferior hæmorrhoidal (third and fourth sacral nerves), and the perineal branch of the fourth sacral nerve. The coccygeal plexus, lastly, supplies the skin round the coccyx (fourth and fifth sacral and coccygeal nerves). Judged from its nerve supply the perineum is to be regarded as occupying, for the most part, a position behind or more caudal than that of the lower limb in relation to the trunk. There is here a remarkable gap in the numerical sequence of the nerves supplying the ventral axis of the body. All the nerves between the first lumbar and the second sacral fail to reach the mid ventral line of the trunk and are wholly concerned in the innervation of the lower limb.

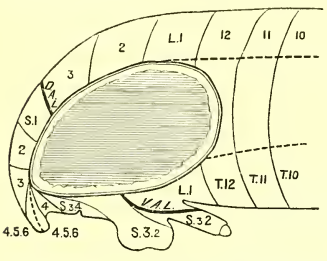


FIG. 514.—SCHEME of the innervation of the hinder portion of the trunk and of the perineum, and the interruption of the segmental arrangement of the nerves associated with the formation of the limb.

T.10, 11, 12, The areas of distribution of the lower thoracic nerves; L.1, 2, 3, The posterior primary divisions of the first three lumbar nerves; L.1, The ilio-inguinal nerve; S.1, 2, 3, 4, 5, 6, The posterior primary divisions of the sacral and coccygeal nerves (6); S.3, 2, S.3, 2, Branches of pudic nerve to penis and scrotum; S.3, 4, Inferior hæmorrhoidal nerve; 4, Perineal branch of the fourth sacral nerve; 4, 5, 6, Anterior sacro-coccygeal nerve; D.A.L, Dorsal axial line; V.A.L, Ventral axial line.

At the preaxial border of the limb (groin) the first lumbar nerve, the highest nerve supplying the perineum, is concerned also in innervating the skin of the limb. At the postaxial border of the limb (fold of the nates and back of the thigh), the nerves which are the highest of those constituting the pudendal plexus (the second and third sacral nerves) are also implicated in innervating that border of the limb. The fourth sacral nerve is only concerned to a very slight extent in the innervation of the limb by means of the perineal branch, which reaches the beginning of its postaxial border; the last two spinal nerves are wholly unrepresented in the limb proper and end entirely in the trunk behind the limb.

DEVELOPMENT OF THE SPINAL NERVES.

I. **Origin of the Spinal Nerve Roots.**—The process of development of the spinal

nerves commences by means of the outgrowth of the **dorsal** and **ventral roots** from the medullary tube. The two roots take origin in quite different ways.

The **dorsal root** is the first to appear,—before, during, or after the union of the medullary plates and the formation of the neural tube. It takes origin as a **cellular bud** from the dorsal surface of the medullary tube in one of three ways:—(1) It may arise from the junction of the medullary plate and surface epiblast before the closure of the medullary groove. (2) It may spring from the *neural crest*, a ridge on the dorsal aspect of the medullary tube, after its closure is complete. (3) It may be simply a direct outgrowth from the dorsal surface of the medullary tube. Pyriform in shape, the bud enlarges and becomes separated from the medullary tube, and projects ventrally in the space between the myotome and the medullary tube. Each bud is separated by only a slight interval from its neighbour.

The cells (**neuroblasts**) composing the bud become rapidly spindle-shaped, and by the middle of the fourth week give rise to *two sets of processes*; (1) a **central series**, which

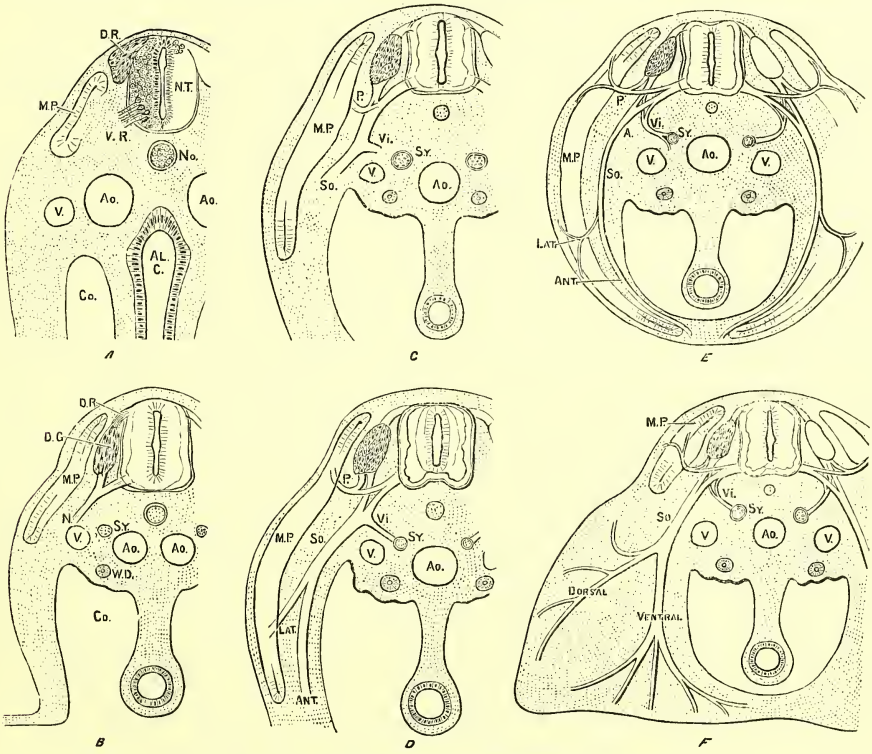


FIG. 515.—DEVELOPMENT OF THE SPINAL NERVES.

A, Formation of nerve roots.

D.R, Dorsal root.
V.R, Ventral root.
N.T, Neural tube.
No, Notochord.
Al.C, Alimentary canal.
Ao, Aorta.
V, Cardinal vein.
M.P, Muscle plate.

B, Formation of nerve trunk (N).

D.G, Dorsal ganglion.
Sy, Sympathetic cord.
W.D, Wolffian duct.
Co, Cœlom.

C, Formation of nerves.

So, Somatic division.
Vi, Visceral branch.
P, Posterior primary division.

D, E, Formation of subordinate branches.

Lat, Lateral, and
Ant, Anterior, branches.

F, Formation of nerve trunks in relation to the limb: dorsal and ventral trunks corresponding to lateral and anterior trunks in D and E.

grow backwards and are secondarily connected with the dorso-lateral aspect of the medullary tube as the fibres of the dorsal root; and (2) a **peripheral series**, which constitute the dorsal root fibres of the spinal nerve and join the ventral root, to form the spinal nerve proper. The intermediate cellular mass remains as the **spinal ganglion**.

The **ventral root** of a spinal nerve arises in quite a different way, from cells (**neuroblasts**) in the substance of the medullary tube. In the account of the development of the spinal cord it has been shown how the cellular constituents of the medullary tube are converted into two classes of cells: (1) **spongioblasts**, which produce the matrix (neuroglia) of the spinal cord; and (2) **germ-cells** or **neuroblasts**, which produce the nerve-cells of the gray matter of the cord. The neuroblasts give rise to the axis-cylinder processes or

axons, which, penetrating the spongy tissue of the medullary tube and the outer limiting membrane, find their way into the mesoblastic tissue on the ventro-lateral surface of the tube. Fibrous from their earliest origin and derived from nerve-cells which remain within the medullary tube, the axons of which the ventral root is composed become surrounded by mesoblastic cells immediately on their emergence, which give rise to the sheaths of the nerve. The ventral root is a little later in its date of appearance than the dorsal root. It begins to be evident at the twenty-fourth day and is completely formed by the twenty-eighth day.

II. **Formation of the Spinal Nerve.**—The fibres of the dorsal root ganglion and the ventral root grow by extension from the cells with which they are respectively connected, and meet in the space between the myotome and the side of the medullary tube to form the **spinal nerve**. It has been already shown that in the adult there is a fundamental division of the spinal nerve into posterior and anterior primary divisions. In the process of development this separation is even more obvious. As the fibres of the dorsal and ventral roots approximate, they separate at the same time each into two unequal portions: the smaller parts of the two roots unite together to form the **posterior**, and the larger parts unite to form the **anterior primary division** of the spinal nerve.

The **posterior primary division**, curving outwards and dorsally, passes through the myotome and is connected with it. In the substance of the myotome it separates into branches as it proceeds towards the dorsal wall of the embryo. At a later stage, the branches are definitely arranged into an outer and an inner set.

The **anterior primary division** grows gradually in a ventral direction to reach the somato-splanchnopleuric angle, under cover of the growing myotome. It spreads out at its distal end and eventually separates into two portions: a smaller, splanchnic, or visceral; and a larger, somatic, or parietal portion. (1) The smaller, **splanchnic**, or **visceral portion** grows inwards, dorsal to the Wolffian ridge, to be connected with the sympathetic cord and the innervation of organs in the splanchnic area. This branch of the spinal nerve becomes the **white ramus communicans** of the sympathetic. It is not present in the case of all the spinal nerves (cervical, lower lumbar, and upper sacral). It will be referred to again in connexion with the sympathetic system. (2) The larger, **somatic**, or **parietal portion** becomes the main part of the anterior primary division of the nerve. It continues the original ventral course of the nerve, and, reaching the body wall, subdivides into two terminal branches—a lateral branch, which grows outwards and downwards and reaches the lateral aspect of the trunk, after piercing the myotome; and a ventral or anterior branch, which grows onwards in the body wall to reach the ventral axis. This arrangement is met with in the trunk between the limbs and in the neck.

III. **Formation of Limb-plexuses.**—The method of growth of the spinal nerves, just described, is modified in the regions where the limbs are developed. In relation to the limbs, which exist in the form of buds of cellular undifferentiated mesoblast before the spinal nerves have any connexion with them, the development of the nerve proceeds exactly in the way described up to the point of formation of somatic and splanchnic branches. The **somatic branches** then stream out into the limb bud, passing into it below the ends of the myotomes and spreading out into a bundle of fibres at the basal attachment of the limb. Later on, the nerves separate each into a pair of definite trunks, which are named **dorsal** and **ventral**, and which, dividing round a central core of mesoblast, proceed to the dorsal and ventral surfaces respectively of the limb bud. While this process is going on, a *secondary union* takes place between (parts of) adjacent dorsal and ventral trunks. Dorsal trunks unite with dorsal trunks, ventral trunks unite with ventral trunks, to form the nerves distributed ultimately to the surfaces and periphery of the limb. These **dorsal and ventral trunks** are homologous with the **lateral and ventral branches** of the somatic nerves in other regions.

Morphology of the Limb-plexuses.

The arrangement of the limb nerves is rendered complex and the significance of the plexuses is obscured by the changes through which, coincidently, the nerves on the one hand and the parts supplied by them on the other hand have passed in the course of development.

Nature of the Limbs.—As already described, the mammalian limbs arise as flattened buds from the extremities of the **Wolffian ridge**. Each bud possesses a *preaxial* and a *postaxial border*, and a *dorsal* and a *ventral surface*, continuous with the dorsal and ventral aspects of the trunk and homologous with its lateral and ventral surfaces. Each bud consists at first of a mass of undifferentiated, unsegmented mesoblast, covered by epithelium. Around the central core of mesoblast which produces the skeletal axis, the vessels and muscles of the limb are formed *in situ*, the muscles as double dorsal and ventral strata, beneath the corresponding surfaces of the bud.

Each limb bud is connected to the lateral and ventral aspects of the trunk, and is associated with a number of body segments, varying in the two extremities and in different animals.

Although the mesoblastic material of which the limb bud is composed exhibits in itself no segmental divisions at any period of its development, a clear indication of the segmental relations of the limbs is obtained from the arrangement of the limb nerves. Taking the nerves which supply the limbs as a guide, the segments engaged in the formation of the upper extremity are the last five cervical and first two thoracic. The lower extremity is related by its nerves to all the lumbar and the first three sacral segments. In each limb, the segments at the preaxial and postaxial borders are only partially concerned in limb formation.

It has been already shown that the somatic branches of the nerves enter the substance of the embryonic limb and divide in their course into dorsal and ventral trunks, which supply the dorsal and ventral surfaces of the limb bud. The higher nerves supply the preaxial border, the lower nerves supply the postaxial border, while the nerves most centrally situated extend furthest towards the periphery of the limb.

In order to understand properly the constitution of the limb-plexuses, it is necessary further to make a comparison of the surfaces and borders of the embryonic and adult limbs.

Upper Limb.—(*A*) **Borders.**—The **preaxial border** of the upper extremity extends from the middle of the clavicle, in the line of the cephalic vein, down the front of the shoulder, the outer side of the arm, forearm and hand, to the outer border of the thumb. The **postaxial border** extends from the middle of the axilla along the inner side of the arm (in the line of the basilic vein), the inner side of the forearm and hand, to the inner border of the little finger.

(*B*) **Surfaces.**—The areas of the limb between these lines, anteriorly and posteriorly, correspond to the ventral and dorsal surfaces of the embryonic limb bud. The **ventral surface** is represented by the front of the chest, arm, and forearm, and the palm of the hand. The **dorsal surface** is represented by the scapular and deltoid regions, the back of the arm, forearm, and hand.

Lower Limb.—(*A*) **Borders.**—The **preaxial border** of the lower limb extends from the middle of Poupart's ligament down the inner side of the thigh and leg in the line of the internal saphenous vein, to the inner side of the great toe. The **postaxial border**, beginning at the coccyx, extends along the fold of the nates and the outer side and back of the thigh and leg (in the line of the external saphenous vein) to the outer border of the foot and little toe.

(*B*) **Surfaces.**—The areas between these lines correspond to the primitive dorsal and ventral surfaces of the embryonic limb bud. The unequal amount of rotation in the parts of the lower limb obscures the relation of fœtal and adult surfaces, which are most easily made out in the infantile position of the limbs, with the thighs and knees flexed and the soles of the feet inverted. The **ventral surface** of the embyronic limb is represented by the inner side and back of the thigh, the back of the leg, and the sole of the foot. The **dorsal surface** is represented by the front of the thigh and buttock, the front of the leg, and the dorsum of the foot.

Composition of the Limb-plexuses.—In all mammals the same definite plan underlies the constitution of the limb-plexuses. The nerves concerned are the anterior primary divisions of certain segmental spinal nerves, which (with certain exceptions at the preaxial and postaxial borders) are destined wholly and solely for the innervation of the limb. Each of the anterior primary divisions engaged divides into a pair of **secondary trunks**, named **dorsal** or posterior, **ventral** or anterior. The dorsal and ventral trunks again subdivide into **tertiary trunks**, which combine with the corresponding subdivisions of neighbouring dorsal and ventral trunks to form the **nerves of distribution**. The combinations of *dorsal trunks* provide a series of nerves for the supply of that part of the limb which is derived from the *dorsal surface* of the embryonic limb bud; the combinations of *ventral trunks* give rise to nerves of distribution to the regions corresponding to its *ventral surface*. The relation of the nerves derived from the limb-plexuses to the areas of the limbs is given in the accompanying tables :—

I. Upper Limb.

Origin.		Nerves.	Distribution.	
Brachial Plexus	Dorsal trunks (*Posterior cord*)	Posterior scapular Posterior thoracic Suprascapular Subscapular (3) Circumflex	Scapular region and shoulder	Dorsal surface
		(Lesser internal cutaneous (?)) (Intercosto-humeral (?))	Arm, inner side	
		Musculo-spiral	Back of arm, forearm, and hand	
	Ventral trunks (*Outer and inner cords*)	Nerve to subclavius Anterior thoracic (2)	Front of chest	Ventral surface
		Musculo-cutaneous	Front of arm and forearm	
		Lesser internal cutaneous	Inner side of arm	
		Internal cutaneous	Front of arm and forearm	
		Median Ulnar	Front of forearm and hand	

II. Lower Limb.

Origin.		Nerves.	Distribution.	
Lumbo-sacral Plexus	Dorsal trunks	Ilio-hypogastric (iliac branch)	Buttock	Dorsal surface
		Superior gluteal		
		Inferior gluteal		
		Nerve to pyriformis		
		Small sciatic	Buttock and thigh, outer side and front	
		External cutaneous	Front of thigh	
		Genito-crural (crural branch)	Front and inner side of thigh, leg, and foot	
		Anterior crural	Front of leg and foot	
		Peroneal		
	Ventral trunks	Ilio-hypogastric (hypogastric branch)	Abdominal wall (ventral surface)	Ventral surface
		Ilio-inguinal	Abdominal wall, thigh, and perineum	
		Genito-crural (genital branch)	Groin	
		Obturator	Thigh (inner side) and knee (back)	
		Nerve to obturator internus and superior gemellus	Buttock and back of thigh	
		Nerve to quadratus femoris and inferior gemellus		
		Nerve to hamstrings		
		Small sciatic	Back of thigh and perineum	
		Tibial	Back of knee, leg, and sole of foot	

In the regions of the limbs no anterior cutaneous branches, derived from the limb nerves, supply the trunk. The whole of the nerve is carried into the limb and is absorbed in its innervation, and the dorsal and ventral trunks forming the limb-plexuses are to be looked upon as homologous with the lateral and anterior trunks of an intercostal nerve. Two series of anomalies in relation to the formation and distribution of the nerves to the limbs must, however, be considered, because it has been suggested (Goodsir) that the nerves of the limbs are serially homologous with not the whole, but with only the lateral branches of the anterior primary divisions of the intercostal nerves.

(1) **Nerves in connexion with the primitive borders of the Limbs.**—**At the preaxial border of the upper limb,** at its root, the fourth cervical nerve, which supplies the anterior and lateral surfaces of the neck, is also distributed through the supraclavicular nerves to the skin of both ventral and dorsal surfaces of the limb. The nerves and surfaces are here not merely homologous, but in actual continuity.

At the preaxial border of the lower limb, similarly, the first lumbar nerve, by means of the ilio-hypogastric and ilio-inguinal branches, supplies on the one hand the buttock, in series with the lateral branches of the lower thoracic nerves, and, on the other hand, the lower part of the abdominal wall and the adjacent inner side of the thigh, in series with the anterior terminal branches of the lower thoracic nerves.

At the postaxial border of the upper limb the first and second thoracic nerves are concerned in supplying trunk segments as well as parts of the limb. The first thoracic nerve, besides supplying the limb through the inner cord of the plexus, also innervates at least the muscles of the first intercostal space ; the second thoracic nerve is concerned in the innervation of the limb, principally by means of its lateral branch only, which, as the intercosto-humeral nerve, supplies the skin along the postaxial border of the limb and on its *dorsal side.* **At the postaxial border of the lower limb,** in the same way, the third and fourth sacral nerves, partially implicated in the innervation of the limb (through the tibial, small sciatic, perforating cutaneous nerve, and perineal branch of the fourth sacral nerve), are also engaged in supplying the trunk (perineum) through the pudic nerve. These peculiarities of arrangement of the nerves at the borders of the limbs may be explained on the supposition that the segment corresponding to the nerve named is only partially concerned in limb formation, and is, at the same time, implicated to a greater or less extent in the formation of structures belonging to the trunk.

(2) **The origin and distribution of the nerves at the postaxial border of the limbs** present a special difficulty. In the composition respectively of the brachial and lumbo-sacral plexuses, the first thoracic and third sacral nerves do not as a rule divide into ventral and dorsal trunks, but contribute only to the formation of the ventral series of nerves. A solution of this difficulty may be found in the examination of the areas of distribution of the nerves derived from the first thoracic and third sacral nerves. In the case of the brachial plexus (the inner cord of which

receives normally the whole contribution of the first thoracic nerve) the lesser internal cutaneous, the inner branch of the internal cutaneous, and the dorsal branch of the ulnar nerve supply the dorsal aspect of the limb on its postaxial border. These nerves are in serial homology with the intercosto-humeral and lateral trunks of intercostal nerves. In the case of the lumbo-sacral plexus similarly, in which the third sacral nerve does not divide into ventral and dorsal trunks, the small sciatic and tibial nerves containing the contribution from the third sacral nerves innervate, by means of the gluteal and external femoral branches of the former and the tibial communicating branch of the latter, the dorsal surface of the limb along the postaxial border, in series with the perforating cutaneous nerve and the perineal branch of the fourth sacral.

These apparent anomalies appear to indicate that, instead of dividing into its proper dorsal and ventral trunks, the entire contribution of the spinal nerve concerned is in these instances carried undivided along the postaxial border of the limb in association with the ventral trunks, and that the dorsal subdivisions are thrown off successively as the plexus cords approach the periphery. Indeed, in the case of the small sciatic nerve, Eisler has shown that, when the peroneal and tibial nerves are separated at their origin, its gluteal and external femoral branches arise from and are connected with the dorsal, and the perineal and internal femoral branches with the ventral trunk.

The Distribution of the Spinal Nerves to the Muscles and Skin of the Limbs.

By dissection, experiment, and clinical observation, it is conclusively proved that as a rule each nerve of distribution in the limb, whether to muscle or skin, is made up of fibres derived from more than one spinal nerve ; and, further, that in cutaneous distribution a considerable overlapping occurs in the course of the several peripheral nerves. Moreover, the arrangement of the distribution of the nerves to skin and to muscles is not identical. In the case of the skin of the limbs, by the covering of the limb being drawn on to it from adjacent parts in the process of growth, cutaneous nerves are engaged, which are derived from sources not represented in the muscular innervation of the limbs. Again, among the muscles, some have undergone fusion, others have become rudimentary, and others again have altered their position in the limb. Bearing these qualifications in mind, it is possible to formulate a definite plan for the innervation of the skin and muscles of the upper and lower limb. The accompanying tables give an analysis of the distribution of the spinal nerves to the skin and muscles of the upper and lower limb respectively :—

I. Upper Limb.

A. Cutaneous Nerves.

1. Dorsal (Posterior) Surface.

Regions.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Scapular — Upper part (*preaxial*)	Posterior primary divisions, cervical	C. 4. 5. 6.	
Scapular — Upper part (*preaxial*)	Cervical plexus, acromial	C. 3. 4.	
Scapular — Lower part (*postaxial*)	Posterior primary divisions, thoracic		T. 1.-7.
Scapular — Lower part (*postaxial*)	Intercostal nerves, lateral branches		T. 2. 3. 4.
Deltoid — Upper part (*preaxial*)	Cervical plexus, acromial	C. 3. 4.	
Deltoid — Upper part (*preaxial*)	Circumflex	C. 5. 6.	
Deltoid — Lower part (*postaxial*)	Intercostal nerves, lateral branches		T. 2. 3.
Upper arm — Outer side (*preaxial*)	Circumflex	C. 5. 6.	
Upper arm — Outer side (*preaxial*)	Musculo-spiral, upper external branch	C. (5). 6.	
Upper arm — Inner side (*postaxial*)	Musculo-spiral, internal branch	C. 8.	
Upper arm — Inner side (*postaxial*)	Lesser internal cutaneous		T. 1.
Upper arm — Inner side (*postaxial*)	Intercosto-humeral		T. 2.

1. **Dorsal (Posterior) Surface**—*continued.*

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Forearm	Outer side (*preaxial*)	Musculo-spiral, upper external branch	C. (5). 6.	
		Musculo-spiral, lower external branch	C. 6. 7. 8.	
		Musculo-cutaneous, posterior branch	C. 5. 6.	
		Radial	C. 6. 7.	
	Inner side (*postaxial*)	Internal cutaneous, internal branch		C. 8. T. 1.
		Ulnar, dorsal branch		C. 8.
Hand	Outer side (*preaxial*)	Radial	C. 6. 7.	
	Inner side (*postaxial*)	Ulnar		C. 8.

I. Upper Limb.

A. Cutaneous Nerves.

2. **Ventral (Anterior) Surface.**

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Chest	Upper part (*preaxial*)	Cervical plexus, supraclavicular branches	C. 3. 4.	
	Lower part (*postaxial*)	Intercostal nerves, anterior branches		T. 2.-7.
		Intercostal nerves, lateral branches		
Upper arm	Outer part (*preaxial*)	Circumflex	C. 5. 6.	
		Musculo-spiral, upper external branch	C. 5. 6.	
	Inner part (*postaxial*)	Internal cutaneous		C. 8. T. 1.
		Lesser internal cutaneous		T. 1.
		Intercosto-humeral		T. 2.
Forearm	Outer part (*preaxial*)	Musculo-cutaneous, anterior branch	C. 5. 6.	
	Inner part (*postaxial*)	Internal cutaneous, anterior branch		C. 8. T. 1.
Hand	Outer part (*preaxial*)	Musculo-cutaneous, ball of thumb	C. 5. 6.	
		Median, palmar branch	C. 6. 7.	
		„ digital branches	C. 6. 7. 8. T. 1.	
		„ thumb, outer side	C. 6. (7).	
		„ „ inner side	C. 6. 7.	
		„ index, outer side		
		„ „ inner side	C (6). 7. 8. (T. 1).	
		„ middle, outer side		
		„ „ inner side		C. 8. T. 1.
		„ ring, outer side		
	Inner part (*postaxial*)	Ulnar, palmar branch		T. 1.
		„ digital branches		T. 1.

I. Upper Limb.

B. Muscular Nerves.

1. Dorsal (Posterior) Surface.

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Shoulder — Upper part (*preaxial muscles*)	Trapezius	Cervical plexus	C. 3. 4.	
	Levator anguli scapulæ	Cervical plexus	C. 3. 4.	
		Posterior scapular	C. 5.	
	Rhomboidei	Posterior scapular	C. 5.	
	Serratus magnus	Posterior thoracic	C. 5. 6. 7.	
	Supraspinatus, Infraspinatus	Suprascapular	C. 5. 6.	
	Subscapularis	Short subscapular, Lower „	C. 5. 6.	
	Teres major	Lower subscapular	C. 5. 6.	
Shoulder — Lower part (*postaxial muscles*)	Teres minor, Deltoid	Circumflex	C. 5. 6.	
	Latissimus dorsi	Long subscapular		C. 6. 7. 8.
Upper arm	Triceps — Outer head	Musculo-spiral	C. (6). 7. 8.	
	Triceps — Middle head, Inner head	Musculo-spiral		C. 7. 8.
	Anconeus	Musculo-spiral		C. 7. 8.
Forearm	Brachio-radialis	Musculo-spiral	C. 5. 6.	
	Extensor carpi radialis longior	Musculo-spiral		C. (5). 6. 7. 8.
	Extensor carpi radialis brevior	Posterior interosseous		C. (5). 6. 7. (8).
	Supinator radii brevis	Posterior interosseous		C. (5). 6.
	Extensor communis digitorum, „ minimi digiti, „ carpi ulnaris	Posterior interosseous		C. (5). 6. 7. 8.
	Extensor ossis metacarpi pollicis, Extensor longus pollicis, „ brevis pollicis, „ indicis	Posterior interosseous		C. (5). 6. 7. 8.

I. Upper Limb.

B. Muscular Nerves.

2. Ventral (Anterior) Surface.

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Pectoral Region — Upper part (*preaxial muscles*)	Sterno-mastoid	Cervical plexus	C. 2.	
	Omo-hyoid, Sterno-hyoid	Ansa hypoglossi	C. 1. 2. 3.	
	Subclavius	Brachial plexus	C. 5. 6.	
Pectoral Region — Lower part (*postaxial muscles*)	Pectoralis major — Clavicular part	Anterior thoracic nerves	C. 5. 6.	C. 5. 6. 7. 8. T. 1.
	Pectoralis major — Sternal part	Anterior thoracic nerves	C. 5. 6.	C. 5. 6. 7. 8. T. 1.
	Pectoralis minor	Anterior thoracic nerves		C. 7. 8. T. 1.

2. **Ventral (Anterior) Surface**—*continued.*

Regions.		Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Upper arm	Outer part (*preaxial*)	Biceps	Musculo-cutaneous	C. 5. 6.	
		Brachialis anticus	Musculo-cutaneous	C. 5. 6.	
			Musculo-spiral	C. (5). 6.	
		Coraco-brachialis	Musculo-cutaneous	C. 7.	
	Inner part (*postaxial*)	Axillary arches	Internal anterior thoracic, or lesser internal cutaneous, or intercosto-humeral		C. 8. T. 1. (2).
Forearm	Outer part (*preaxial*)	Pronator radii teres	Median	C. 6.	
		Flexor carpi radialis	Median	C. 6.	
		Palmaris longus	Median		
		Flexor sublimis digitorum	Median		
		Flexor profundus digitorum	Anterior interosseous : Ulnar		C. 7. 8. T. 1. C. 8. T. 1.
		Flexor carpi ulnaris	Ulnar		C. 8. T. 1.
	Inner part (*postaxial*)	Flexor longus pollicis	Anterior interosseous	C. 7. 8. T. 1.	
		Pronator quadratus	Anterior interosseous	C. 7. 8. T. 1.	
Hand	Outer part (*preaxial*)	Abductor pollicis	Median	C. 6. 7.	
		Opponens pollicis	Median	C. 6. 7.	
		Flexor brevis pollicis	Median	C. 6. 7.	
		Two outer lumbricales	Median	C. 6. 7.	
		Two inner lumbricales	Ulnar		C. 8. (T. 1).
		Interossei	Ulnar		C. 8. (T. 1).
		Adductores pollicis (transversus et obliquus)	Ulnar		C. 8. (T. 1).
		Abductor minimi digiti	Ulnar		C. 8. (T. 1).
	Inner part (*postaxial*)	Opponens minimi digiti	Ulnar		C. 8. (T. 1).
		Flexor brevis minimi digiti	Ulnar		C. 8. (T. 1).

II. Lower Limb.

A. Cutaneous Nerves.

1. Dorsal Surface.

(*Front and outer side of thigh, buttock, front of leg, dorsum of foot.*)

Regions.		Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Front of thigh and front part of buttock (*preaxial nerves*)	Thigh	Genito-crural, crural branch	L. 1. 2.	
		Anterior crural, internal branch	L. 2. 3.	
		Anterior crural, middle branch	L. 2. 3.	
		External cutaneous	L. 2. 3.	
	Buttock	Twelfth thoracic, iliac branch	T. 12.	
		Ilio-hypogastric, iliac branch	L. 1.	
		Posterior primary divisions, lumbar	L. 1. 2. 3.	
		Posterior primary divisions, sacral		S. 1.-5.
Outer side of thigh and buttock, back and lower part (*postaxial nerves*)		Posterior primary divisions, coccygeal		Co.
		Small sciatic : gluteal, and femoral branches		S. 1. 2. 3.
Leg	Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
		Patellar branch	L. 3. 4.	
	Outer side (*postaxial*)	Musculo-cutaneous	L. 4. 5. S. 1.	
		Peroneal, sural branches	L. (4). 5. S. 1.	
Dorsum of foot	Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
		Anterior tibial	L. 4. 5. (S. 1).	
	Outer side (*postaxial*)	Musculo-cutaneous	L. 4. 5. S. 1.	
		External saphenous		S. 1. (2).

II. Lower Limb.

A. Cutaneous Nerves.

2. Ventral Surface.

(*Inner side and back of thigh, back of leg, and sole of foot.*)

Regions.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Inner side and back of thigh — Inner side of thigh (*preaxial*)	Ilio-inguinal	L. 1.	
	Obturator	L. 2. 3. (4).	
Inner side and back of thigh — Back of thigh (*postaxial*)	Small sciatic, femoral branches		S. 1. 2. 3.
Back of leg	Peroneal, sural branches	L. (4). 5.	S. 1.
	Peroneal, communicans fibularis	L. (4). 5.	S. 1.
	Small sciatic		S. 1. 2. 3.
	External saphenous		S. 1. (2).
Sole of foot — Inner side (*preaxial*)	Internal saphenous	L. 3. 4.	
	Posterior tibial, calcanean		S. 1. 2.
	Internal plantar	L. 4. 5.	S. 1.
	Great toe, inner side	L. 4. 5.	
	„ „ outer side	L. 4. 5.	S. 1.
	Second toe, inner side	L. 4. 5.	S. 1.
	„ „ outer side	L. 5.	S. 1.
	Third toe, inner side	L. 5.	S. 1.
	„ „ outer side	L. 5.	S. 1.
	Fourth toe, inner side	L. 5.	S. 1.
Sole of foot — Outer side (*postaxial*)	External plantar		S. 1. 2.
	Fourth toe, outer side		S. 1. 2.
	Fifth toe, inner side		S. 1. 2.
	„ „ outer side		S. 1. 2.
	External saphenous		S. 1. (2).

II. Lower Limb.

B. Muscular Nerves.

1. Dorsal Surface.

(*Front and outer side of thigh, buttock, front and outer side of leg, dorsum of foot.*)

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Front of thigh (*preaxial*)	Pectineus	Anterior crural	L. 2. 3.	
	Sartorius	Anterior crural	L. 2. 3.	
	Iliacus	Anterior crural	L. 2. 3. 4.	
	Psoas	Anterior crural	L. 2. 3. 4.	
	Quadriceps extensor	Anterior crural	L. 3. 4.	
	Vastus internus	Anterior crural	L. 3. 4.	
	Rectus femoris	Anterior crural	L. 3. 4.	
	Crureus	Anterior crural	L. 3. 4.	
	Vastus externus	Anterior crural	L. 3. 4.	
Buttock and outer side of thigh (*postaxial*)	Tensor fasciæ femoris	Superior gluteal	L. 4. 5.	S. 1
	Gluteus minimus	Superior gluteal	L. 4. 5.	S. 1
	„ medius	Superior gluteal	L. 4. 5.	S. 1
	„ maximus	Inferior gluteal	L. 5.	S. 1. 2.
	Biceps, short head	Peroneal	L. 5.	S. 1. 2.
	Pyriformis	Sacral plexus		S. 1. 2.

1. **Dorsal Surface**—*continued.*

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*
Front of leg, Inner side (*preaxial*)	Tibialis anticus	Anterior tibial	L. 4. 5. S. 1.
	Extensor proprius hallucis		
	Extensor longus digitorum		
	Peroneus tertius		
Front of leg, Outer side (*postaxial*)	Peroneus longus	Musculo-cutaneous	
	Peroneus brevis		
Dorsum of foot	Extensor brevis digitorum	Anterior tibial	

II. Lower Limb.

B. Muscular Nerves.

2. **Ventral Surface.**

(*Inner side and back of thigh, back of leg, and sole of foot.*)

Regions.	Muscles.	Nerves.	Spinal Origins. *Preaxial Nerves.*	Spinal Origins. *Postaxial Nerves.*
Thigh and buttock, Thigh, inner side (*preaxial*)	Adductor longus	Obturator	L. 2. 3.	
	Gracilis		L. 2. 3. 4.	
	Adductor brevis		L. 3. 4.	
	Obturator externus			
	Adductor magnus			
Thigh and buttock, Thigh, outer side (*postaxial*)	Adductor magnus	Nerve to hamstrings	L. 4. 5. S. 1.	
	Semi-membranosus		L. 5. S. 1. 2.	
	Semi-tendinosus		S. 1. 2. 3.	
	Biceps, long head			
Thigh and buttock, Buttock	Quadratus femoris and superior gemellus	Sacral plexus	L. 4. 5. S. 1.	
	Inferior gemellus and obturator internus		S. 1. 2. 3.	
Back of leg	Plantaris	Tibial	L. 4. 5. S. 1.	
	Popliteus			
	Flexor longus digitorum	Posterior tibial	L. 5. S. 1.	
	Tibialis posticus			
	Flexor longus hallucis		L. 5. S. 1. 2.	
	Soleus			
	Soleus	Tibial	S. 1. 2.	
	Gastrocnemius (each head)			
Sole of foot, Inner side (*preaxial*)	Abductor hallucis	Internal plantar	L. 4. 5. S. 1.	
	Flexor brevis digitorum			
	Flexor brevis hallucis			
	First lumbricalis			
Sole of foot, Outer side (*postaxial*)	Second, third, and fourth lumbricales	External plantar	S. 1. 2.	
	Flexor accessorius			
	Adductores hallucis			
	Interossei			
	Flexor brevis minimi digiti			
	Abductor minimi digiti			

A. **Innervation of the Muscles of the Limbs.**—The following laws appear to be applicable to the upper and lower limbs alike :—

1. *No limb-muscle receives its nerve-supply from posterior primary divisions.*

2. *The dorsal and ventral strata of muscles are always supplied by the corresponding dorsal and ventral branches of the nerves concerned. The ventral muscular stratum is more extensive than the dorsal; the ventral nerves are the more numerous, and the additional nerves are postaxially placed.* The spinal nerves supplying muscles of the upper limb are C. 5, 6, 7, 8 (dorsal), and C. 5, 6, 7, 8, T. 1 (ventral); the nerves for the muscles of the lower limb are L. 2, 3, 4, 5, S. 1, 2 (dorsal), and L. 2, 3, 4, 5, S. 1, 2, 3 (ventral).

3. *The dorsal and ventral trunks of the nerves are distributed in the limb in a continuous, segmental manner*; so that, "of two muscles, that nearer the head end of the body tends to be supplied by the higher nerve, and that nearer the tail end by the lower nerve" (Herringham).

4. *The nerves placed most centrally in the plexus extend furthest into the limb, and the more preaxial nerves terminate sooner in the limb than the more postaxial nerves.*

Upper Limb.

Dorsal Surface.		Ventral Surface.	
Muscles of shoulder	C. 3, 4, 5, 6, 7, 8.	Muscles of chest	C. 5, 6, 7, 8, T. 1.
„ arm	C. 6, 7, 8.	„ arm	C. 5, 6, 7.
„ forearm	C. 6, 7.	„ forearm	C. 6, 7, 8, T. 1.
		„ hand	C. 6, 7, 8 (T. 1).

Lower Limb.

Muscles of thigh and buttock	L. 2, 3, 4, 5, S. 1, 2.	Muscles of thigh	L. 2, 3, 4, 5, S. 1, 2, 3.
Muscles of leg and foot	L. 4, 5, S. 1.	„ leg	L. 4, 5, S. 1, 2.
		„ foot	L. 5, S. 1, 2.

The only exception to this rule is on the ventral (anterior) surface of the upper arm, where a suppression of the muscle elements leads to an absence of the regular series of segmental nerves (C. 8, T. 1) on its postaxial border. These nerves reappear in the forearm, and the occasional

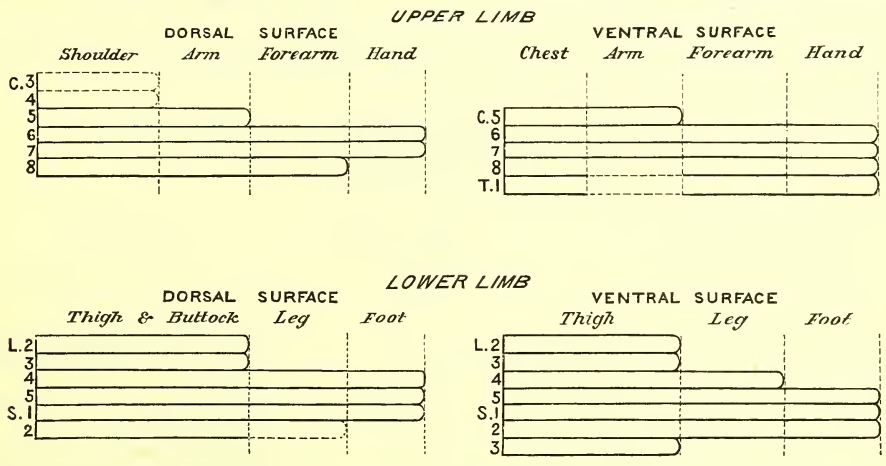


FIG. 516.—SCHEME of the segmental distribution of the muscular nerves of the upper and lower limbs.

"axillary arches" may be regarded as the muscular elements usually suppressed, and, when present, supplied by these nerves.

Muscles with a Double Nerve-supply.—The existence of more than one nerve to a muscle indicates usually that the muscle is composite and is the representative of originally separate elements, belonging to more than one segment or to both surfaces of the limb. In the case of the pectoralis major, subscapularis and flexor profundus digitorum, adductor magnus, and soleus, parts of the same (ventral or dorsal) stratum have fused, to form muscles innervated from the corresponding ventral or dorsal nerves. The other muscles having a double nerve-supply—brachialis anticus, biceps flexor cruris, and (sometimes) pectineus—are examples of fusion at the preaxial or postaxial border of muscular elements derived from the dorsal and ventral surfaces of the limb, which are correspondingly innervated by branches from both dorsal and ventral series: *e.g.* the brachialis anticus is innervated by the musculo-cutaneous and musculo-spiral nerves; the biceps flexor cruris, by the peroneal (short head) and tibial (long head) nerves; and the pectineus, by the anterior crural and (sometimes) obturator nerves.

B. **Innervation of the Skin of the Limbs.**—While the scheme of cutaneous innervation of the limbs is fundamentally segmental, yet the arrangement is confused and complicated by various causes. The growth of the limb from the trunk has caused the skin to be drawn out over it like a stretched sheet of india-rubber (Herringham), and at the same time the extent of the dorsal area of the limb is increased at the expense of the ventral area. The central nerves of the plexus remain buried deeply in the substance of the limb, only coming to the surface towards the periphery. The proximal parts of both surfaces of the limb thus become innervated by

cutaneous nerves otherwise not necessarily concerned in the innervation of the limbs. Herringham has shown that—(A) *Of two spots on the skin, that nearer the preaxial border tends to be supplied by the higher nerve.* (B) *Of two spots in the preaxial area, the lower tends to be supplied by the lower nerve; and of two spots in the postaxial area, the lower tends to be supplied by the higher nerve.* In other words, from the root of the limb down the preaxial border to its distal extremity, and up the postaxial border to the root of the limb again, there is a definite numerical sequence of spinal nerves supplying skin areas through nerves of the limb-plexuses. A similar numerical sequence in the arrangement of the nerves is also found extending over the dorsal and ventral surfaces of the limbs from preaxial to postaxial border, except in certain situations.

On the dorsal and ventral surfaces of both upper and lower limbs there is a hiatus, for a certain distance, in the numerical sequence of the spinal nerves in their cutaneous distribution, explicable on the ground that the central nerves of the plexus, which fail to reach the surface in these situations, are replaced by cutaneous branches from neighbouring nerves. This hiatus has been named the *axial area or line.*

In the upper limb, *the dorsal axial area or line* extends from the middle line of the back, opposite the vertebra prominens, to the insertion of the deltoid.

The ventral axial area or line extends anteriorly from the middle line of the trunk, at the manubrio-sternal joint, across the chest, down the front of the arm and forearm to the wrist.

In the lower limb, *the dorsal axial area or line* may be traced from the middle line of the back over the posterior superior iliac spine, across the buttock and thigh, to the head of the fibula.

A ventral axial area or line can also be traced from the root of the penis along the inner side of the thigh and knee, and down the back of the leg to the heel.

These areas or lines represent the meeting-place and overlapping of nerves, which are not in numerical sequence; and it is only at the peripheral parts of the limbs, on the dorsal and ventral surfaces, that the nerves appear in numerical sequence from the preaxial to the postaxial border. In the case of the upper limb the hiatus is caused, in both surfaces of the limb, by the absence of cutaneous branches of the seventh cervical nerve; in the case of the lower limb the hiatus is due to the absence of branches from the fifth lumbar nerve on both surfaces of the limb, and the absence of branches from the fourth lumbar nerve, in addition, on the dorsal surface.

Understanding the significance of these dorsal and ventral axial areas or lines, and at the same time bearing in mind the overlapping which occurs in the cutaneous distribution of each spinal nerve, the areas of skin supplied through the limb-plexuses can be mapped out with considerable precision, as indicated in the following tables:—

A. Upper Limb.

Cutaneous Distribution.

Nerves.		Spinal Origin.	Distribution.
Preaxial border from neck to hand ↓	Supraclavicular nerves	C. 3. 4.	Chest, shoulder, deltoid, and scapular regions.
	Circumflex	C. 5. 6.	Deltoid region, outer side of arm.
	Musculo-spiral (upper external)	C. (5). 6.	Outer side and back of arm and forearm.
	Musculo-spiral (lower external)	C. 6. 7. 8.	Outer side and back of elbow and forearm.
	Musculo-cutaneous	C. 5. 6.	Outer side of forearm, in front and behind.
Hand — Dorsum	Radial	C. 6. 7.	Outer side of dorsum of hand.
	Ulnar	C. 8.	Inner side of dorsum of hand.
Hand — Palm	Musculo-cutaneous	C. 5. 6.	Ball of thumb.
	Median	C. 6. 7.	Outer side of palm of hand.
	Ulnar	T. 1.	Inner side of palm of hand.
Digits	Median	C. 6. 7. 8. T. 1.	Thumb C. 6. 7.; First finger, C. 6. 7. 8.; Second „ C. 7. 8. T. 1.
	Ulnar	C. 8. T. 1.	Third „ C. 8. T. 1.; Fourth „ Fifth „ T. 1.
Postaxial border from hand to chest ↑	Internal cutaneous	C. 8. T. 1.	Inner side of forearm, in front and behind.
	Musculo-spiral (internal)	C. 8.	Inner side of arm.
	Lesser internal cutaneous	T. 1.	
	Intercosto-humeral	T. 2.	
	Intercosto-humeral	T. 2.	Axillary folds.
	Third intercostal	T. 3.	
	Fourth „	T. 4.	

B. Lower Limb.

Cutaneous Distribution.

Nerves.		Spinal Origin.	Distribution.
Preaxial border from trunk to foot ↓	Iliac branch of twelfth thoracic	T. 12.	Outer side of buttock.
	Iliac branch of ilio-hypogastric	L. 1.	Outer side of buttock.
	Ilio-inguinal	L. 1.	Groin and over Scarpa's triangle.
	Genito-crural	L. 1. 2.	Front of thigh, upper third.
	External cutaneous	L. 2. 3.	Front and outer side of thigh.
	Anterior crural (middle and internal)	L. 2. 3.	Front and inner side of thigh, lower two-thirds.
	Obturator	L. 2. 3. (4).	Inner side of thigh, middle third.
	Anterior crural (internal saphenous)	L. 3. 4.	Knee and leg, inner side and front.
Foot — Dorsum	Internal saphenous	L. 3. 4.	Inner side of foot.
	Anterior tibial	L. 4. 5. S. (1).	Interval between first and second toes.
	Musculo-cutaneous	L. 4. 5. S. 1.	Dorsum of foot and toes.
	External saphenous	S. 1. (2).	Outer side of foot.
Foot — Sole	Internal plantar	L. 4. 5. S. 1.	Inner part of sole.
	External plantar	S. 1. 2.	Outer part of sole.
	Posterior tibial (calcanean)	S. 1. 2.	Heel and back part of sole.
Digits	Internal and external plantar	L. 4. 5. S. 1. S. 1. 2.	Great toe, L. 4. 5. S. 1. Second toe, L. 4. 5. S. 1. Third „ L. 5. S. 1. Fourth „ L. 5. S. 1. 2. Fifth „ S. 1. 2.
Postaxial border from foot to coccyx ↑	External saphenous	S. 1. (2).	Outer side of foot and leg, lower third.
	Small sciatic	S. 1. 2. 3.	Back of leg, thigh, and buttock.
	Perforating cutaneous	S. 2. 3.	Buttock (fold of nates, inner half).
	Sacro-coccygeal	S. 4. 5. Co. 1.	Anal fold.

Variations in the Position of the Limb-plexuses.

Two different kinds of variations occur in relation to the limb-nerves.

(1) **Individual variations,** in both the extent of origin and in the area of distribution of a given nerve, are not uncommon; these variations are usually concomitant with compensatory variations in adjacent nerves, and are due to the fibres of a given spinal nerve taking an abnormal course in the trunk of another nerve of distribution and effecting a communication with the proper nerve peripherally. In this way the variations in the origin and distribution of the intercosto-humeral nerve may be explained; and, similarly, the ulnar nerve may have some of its fibres carried as far as the forearm incorporated with the median and transferred to it by a communication between the two nerves in that region.

(2) **Variations in the limb-plexus,** in relation to the vertebral column, are the chief cause of variations in the constitution of the limb-nerves. These variations affect more or less the whole series of nerves in the plexus.

The **brachial plexus** is subject only to very slight variation in position and arrangement. It may be reinforced at the upper end by a slender trunk from the fourth cervical nerve, and, more frequently, by an intra-thoracic communication between the second and first thoracic nerves. The presence of one or other of these nerves is an indication of a slight tendency towards a cephalic or caudal shifting of the whole plexus in relation to the spinal cord. It is, however, never sufficient to cause the exclusion to any extent of the nerves normally implicated. The presence of a cervical rib may coincide with little or no change in the relation of the nerves. Indeed, the inclusion of the second thoracic nerve in the plexus may be, as already stated, merely an individual variation, a change in the path to the limb of the intercosto-humeral nerve. Concomitant variations occur among groups of nerves, however, which indicate a certain tendency to variation in the position of the whole plexus. At one end, the suprascapular and musculo-cutaneous nerves may arise from the fourth and fifth, fifth alone, or fifth and sixth cervical nerves. At the other end of the plexus, the musculo-spiral may or may not receive a root from the first thoracic nerve, and this addition is rather more likely to occur when the second thoracic nerve is implicated in the plexus.

The **lumbo-sacral plexus** shows a very considerable variability in position and constitution. Eisler records concomitant variations in the plexus in 18 per cent of the cases examined by him.

The variations occur within wide limits. The plexus may begin at the eleventh or twelfth thoracic or first lumbar nerve. The last nerve in the great sciatic cord may be the second, third, or fourth sacral nerve. The position of the n. furcalis is a guide to the arrangement of the plexus. It may be formed by the third, third and fourth, fourth, fourth and fifth, or fifth lumbar nerves. The resulting variations are illustrated by the following extreme cases:—

	(1) *Prefixed Variety.*	(2) *Postfixed Variety.*
Nervus furcalis	L. 3 and 4 (double).	L. 5.
Obturator	L. 1, 2, 3.	L. 2, 3, 4, 5.
Anterior crural	T. 12, L. 1, 2, 3, 4.	L. 2, 3, 4, 5.
Tibial	L. 3, 4, 5, S. 1, 2.	L. 5, S. 1, 2, 3, 4.
Peroneal	L. 3, 4, 5, S. 1.	L. 5, S. 1, 2, 3.

Those variations in the constitution of the lumbo-sacral plexus are most numerous which are due to the inclusion of nerves more caudally placed. Thus, out of twenty-two variations in the position of the *n. furcalis*, in nineteen Eisler found it formed by the fifth lumbar nerve; in two cases only, by the third lumbar nerve. There is further evidence that variations in the position of the plexus are accompanied by variations in the vertebral column itself. Out of the twenty-two abnormal plexuses examined by Eisler, sixteen were coincident with abnormal arrangement of the associated vertebræ.

Significance of the Limb-plexuses.

From the above considerations, it is obvious that something more than convenience of transit for the spinal nerves to skin and muscles is secured by the formation of the limb-plexuses. It has been shown that by their combinations in the plexuses, every spot or area of skin in the limbs is innervated by more than one spinal nerve; and generally, also, each limb-muscle is supplied by more than one spinal nerve. Each cutaneous area and each limb-muscle is thus brought into relationship with a wider area of the spinal cord than would occur if the plexuses were non-existent. A simultaneous record of sensation is thus transmitted from any given point on the surface of the limb through more than one dorsal root; and a more ready co-ordination of muscular movement is brought about by the transmission of motor impulses from the ventral root of a given spinal nerve to more than one muscle at the same time. In a word, a plexus exists to supply the whole limb and the limb as a whole, as an organ which has its different active parts connected with the central nervous system by means of the limb-plexus.

THE CRANIAL NERVES.

The series of cranial nerves is arranged in twelve pairs, which present striking differences in origin, in distribution, and in functions.

Number.	Name.	Function.	Superficial Attachment to Brain.
I.	**Olfactory**	Smell	Olfactory bulb.
II.	**Optic**	Sight	Optic thalamus.
III.	**Oculo-motor**	Motor to the muscles of eyeball and orbit	Crus cerebri.
IV.	**Trochlear**	Motor to superior oblique muscle of eyeball	Superior medullary velum.
V.	**Trigeminal**	Sensory to face, tongue, and teeth; motor to muscles of mastication	Pons Varolii.
VI.	**Abducent**	Motor to external rectus muscle of eyeball	Junction of pons and medulla.
VII.	**Facial**	Motor to muscles of scalp and face, sensory to tongue	Posterior border of pons Varolii.
VIII.	**Auditory**	Hearing and equilibrium	Posterior border of pons Varolii
IX.	**Glosso-pharyngeal**	Sensory to tongue and pharynx	Medulla oblongata.
X.	**Pneumogastric**	Sensory to pharynx, œsophagus and stomach, and respiratory organs	Medulla oblongata.
XI.	**Spinal accessory**	(*a*) **Accessory to vagus.**—Motor to muscles of palate, pharynx, œsophagus, stomach and intestines, and respiratory organs; inhibitory for heart	Medulla oblongata.
		(*b*) **Spinal part:** motor to trapezius and sterno-mastoid muscles	Spinal cord.
XII.	**Hypoglossal**	Motor to muscles of the tongue	Medulla oblongata.

The deep cerebral connexions of the cranial nerves are dealt with in the section which treats of the Brain (pp. 514 and 540). Certain general points in connexion with these nerves are also touched upon in the chapter introductory to the Nervous System (p. 443).

The First or Olfactory Nerve.

The olfactory nerve (n. olfactorius) consists of several parts: (1) a series of fine **nerves**, which arise from (2) the **olfactory bulb**. This again is connected by (3)

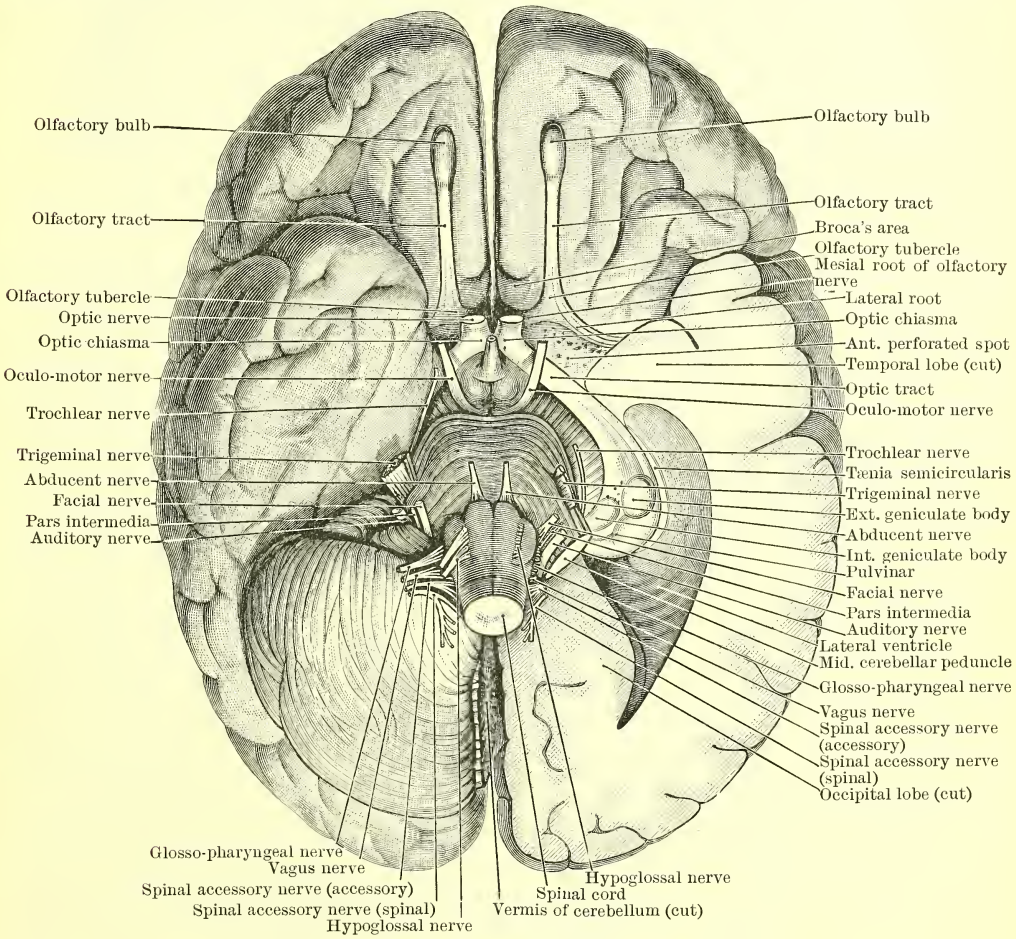


Fig. 517.—View of the Under Surface of the Brain, with the lower portion of the temporal and occipital lobes, and the cerebellum on the left side removed, to show the origins of the cranial nerves.

the **olfactory tract** with the brain, to which it is attached by (4) two **roots** (Fig. 517).

The anatomy of the roots, tract, and bulb of the olfactory nerve are described elsewhere (pp. 569 and 587).

The **olfactory nerves**, about twenty in number, arise from the under surface of the olfactory bulb. The fibres are non-medullated. Piercing the cribriform plate of the ethmoid bone, enveloped in sheaths of dura mater, they are distributed in the nasal cavity as the nerves of smell. The fibres form fine plexuses over a limited area on the upper portion of the nasal septum, and to even a less extent over the outer wall of the nose.

The Second or Optic Nerve.

The optic nerve (n. opticus) arises from the brain by means of the **optic tract** (Fig. 551). This takes origin from the external and internal geniculate bodies,

situated on the under surface of the optic thalamus at its posterior end, and also from the brachium of the upper of the two corpora quadrigemina (*vide* pp. 532 and 551). The optic tract reaches the base of the brain after sweeping round

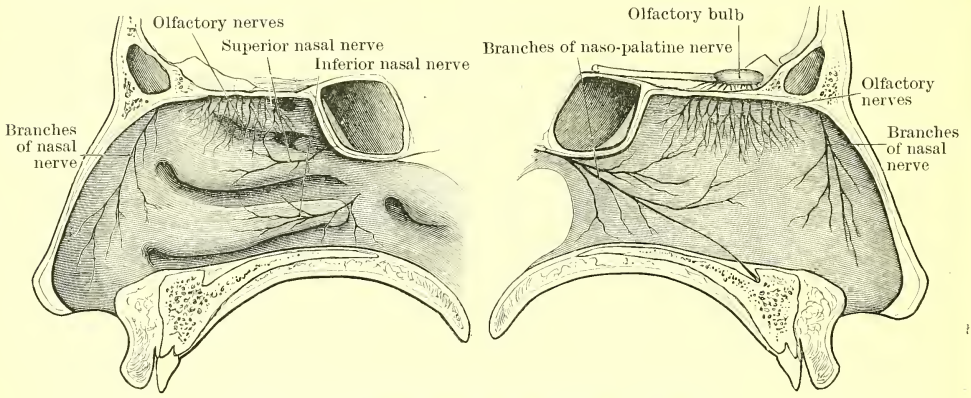


Fig. 518.—Innervation of the Nasal Cavity.

between the crus cerebri and the hippocampal convolution of the temporal lobe. The two optic tracts converge in front of the inter-peduncular space, internal to the anterior perforated spot and the termination of the internal carotid artery, and unite to form the **optic chiasma** or **commissure**. This adheres to the under surface of the floor of the third ventricle in front of the tuber cinereum, and gives rise at each end to the **optic nerve**. The optic nerve, directed outwards and forward, pierces the dura mater, and passes from the cranial cavity into the orbit through the optic foramen in company with the ophthalmic artery. In the orbit the nerve is imbedded in the fat behind the eyeball, and is surrounded by the ocular muscles. It is connected with the globe of the eye at a point one-eighth of an inch on the inner side of the axis of the eyeball. After piercing the fibrous and vascular coats, the nerve spreads out at the **optic disc** to form the innermost layer of the **retina**. In the orbit the nerve is crossed by the ophthalmic artery and the nasal nerve, and nearer to its termination it is surrounded by the ciliary vessels and nerves, and by the capsule of Tenon. It is pierced obliquely on its under surface by the central artery of the retina.

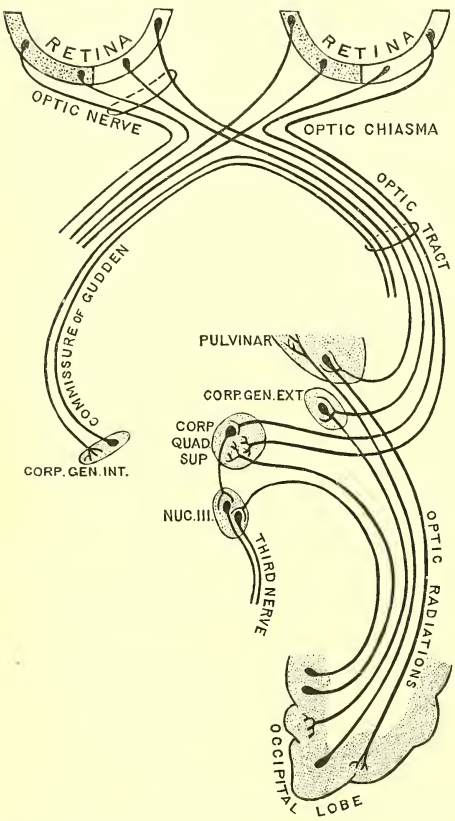


Fig. 519.—Diagram of the Central Connexions of the Optic Nerve and Optic Tract.

Decussation in the Optic Commissure.—In the optic commissure the fibres of the two optic tracts separate, the inner half of each tract decussating to form the mesial half of the opposite optic nerve. The other, outer half of each tract, continues its course to form the outer half of the optic nerve on the same side. At the back of the commissure another bundle of fibres is found passing from tract to tract behind the decussating fibres, and known as **Gudden's commissure** (see p. 552).

The Third or Oculo-motor Nerve.

The oculo-motor nerve (n. oculo-motorius) arises from the brain, in the region of the posterior perforated spot, by several radicles emerging from the **oculo-motor**

sulcus, on the inner side of the crus cerebri, just in front of the pons Varolii (Fig. 517). Passing forwards between the posterior cerebral and superior cerebellar arteries, the nerve pierces the dura mater on the outer side of the posterior clinoid process, in a small triangular space between the free and attached borders of the tentorium cerebelli. Beneath the dura mater the nerve courses through the outer wall of the cavernous sinus, and enters the orbit through the sphenoidal fissure

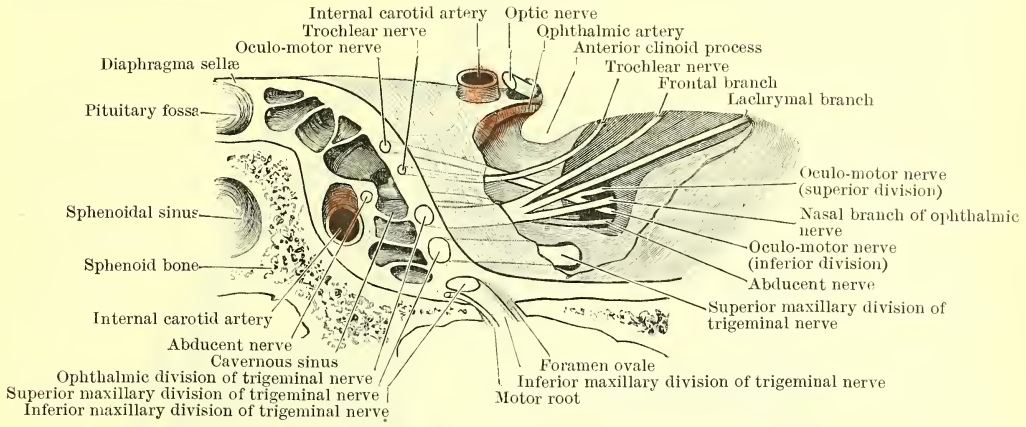


FIG. 520.—RELATIONS OF STRUCTURES IN THE CAVERNOUS SINUS AND SPHENOIDAL FISSURE.

and between the two heads of the external rectus muscle. As it enters the orbit it divides into upper and lower branches, separated by the nasal nerve.

Branches.—The **superior branch** of the nerve supplies two muscles of the orbit —the superior rectus and the levator palpebræ superioris.

The **inferior branch** passes forwards, and after giving branches to the internal and inferior recti, ends in the inferior oblique muscle. The short root of the ciliary ganglion arises from the terminal branch which goes to the last-named muscle.

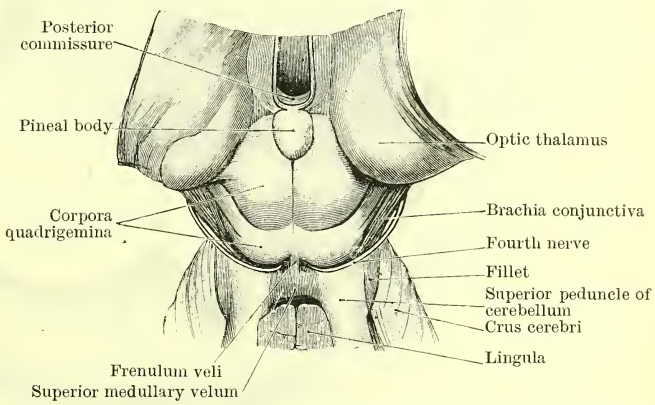


FIG. 521.—DORSAL SURFACE OF THE MID-BRAIN, to show the origin of the trochlear (fourth) nerve.

Communications.—1. In the cavernous sinus the third nerve communicates with the cavernous plexus on the internal carotid artery. 2. In the cavernous sinus it also receives a slender communication from the ophthalmic division of the fifth nerve. 3. The **short root of the ciliary ganglion** passes upwards from the branch of the nerve which supplies the inferior oblique muscle.

THE FOURTH OR TROCHLEAR NERVE.

The trochlear nerve (n. trochlearis or patheticus) emerges from the dorsal surface of the mid-brain. It springs at the side of the *frenulum* from the anterior end of the superior medullary velum, just behind the corpora quadrigemina (for deep origin, see p. 540). It is extremely slender, and of considerable length. Passing round the crus cerebri, the nerve appears in the base of the brain behind the optic tract, in the interval between the crus cerebri internally and the temporal lobe of the cerebrum externally. Continued forwards to the base of the skull, it pierces the free border of the tentorium cerebelli, on the outer side

of the third nerve, and proceeds forwards in the outer wall of the cavernous sinus, to the sphenoidal fissure lying between the third and ophthalmic nerves. It enters the orbit above the muscles of the eyeball, and terminates in the orbital (superior) surface of the superior oblique muscle.

Communications.—In the cavernous sinus the nerve receives (1) a communicating

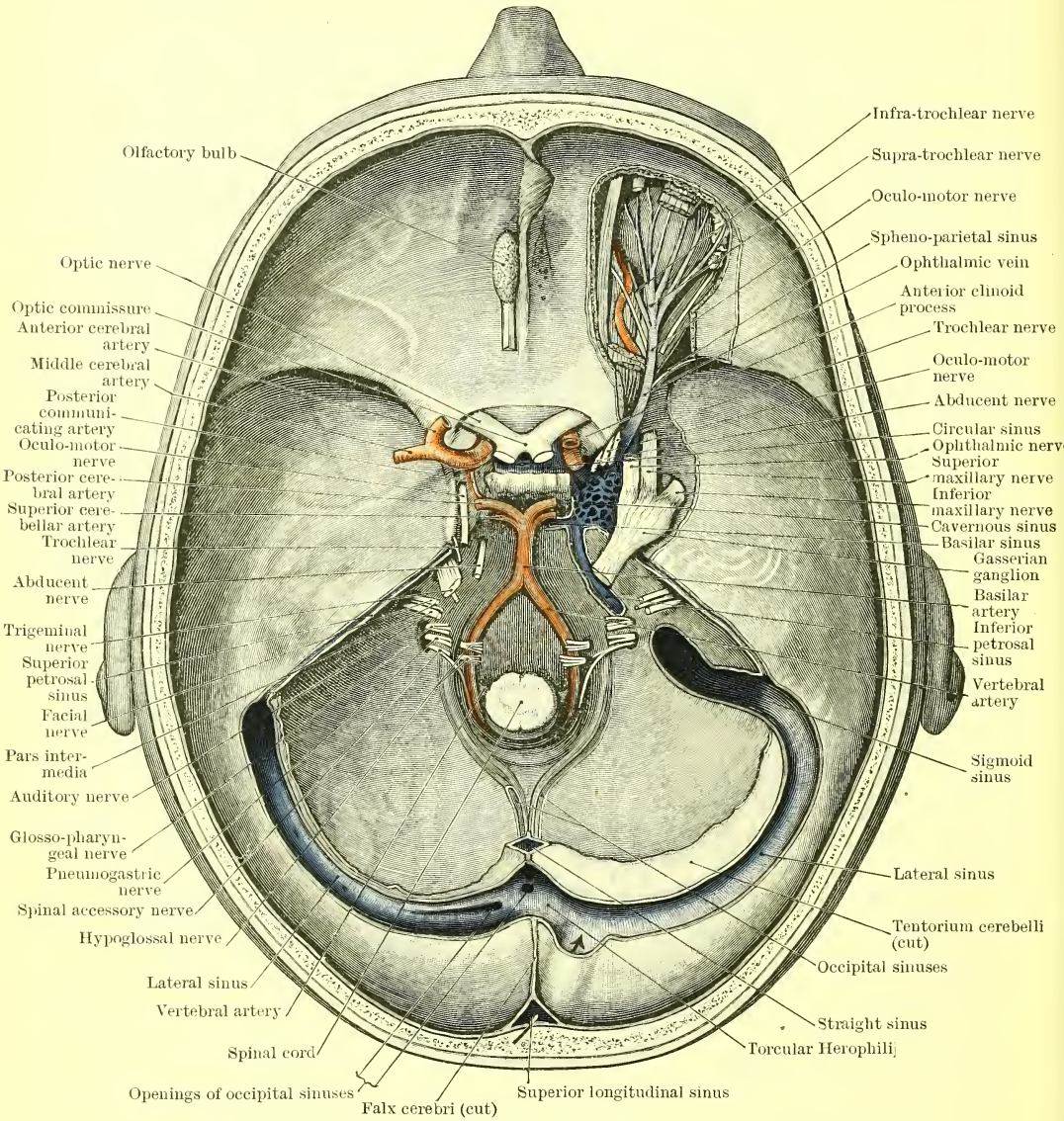


FIG. 522.—THE BASE OF THE SKULL, to show the dura mater, sinuses, arteries, and nerves.

branch from the cavernous or carotid plexus on the internal carotid artery, and (2) a slender filament from the ophthalmic division of the fifth nerve.

THE FIFTH, TRIGEMINAL OR TRIFACIAL NERVE.

The trigeminal nerve (n. trigeminus) arises from the surface of the pons Varolii in its outer part by two roots, a large **sensory root** (portio major) and a small **motor root** (portio minor) (Fig. 517, p. 675). The two roots proceed forwards in the posterior fossa of the base of the skull, and piercing the dura mater beneath the attachment of the tentorium cerebelli to the superior border of the petrous portion of the

temporal bone, enter a cavity in the dura mater (cavum Meckelii) over the apex of the petrous bone. The large sensory root gradually conceals the small motor root in its course forwards, and expands beneath the dura mater into a large flattened ganglion,—the **Gasserian ganglion** (ganglion semilunare). This ganglion occupies an impression on the apex of the petrous portion of the temporal bone, and from it three large trunks arise—the ophthalmic or first, the superior maxillary or second, and the inferior maxillary or third divisions of the nerve. The small motor root of the nerve passes forward beneath the Gasserian ganglion, and is wholly incorporated with the inferior maxillary division of the nerve.

Ophthalmic Division (n. ophthalmicus).—The ophthalmic nerve passes forwards to the orbit through the middle fossa of the base of the skull, beneath the dura mater. It lies in the outer wall of the cavernous sinus, at a lower level than the fourth nerve, and reaches the orbit through the sphenoidal fissure (Fig. 520).

In the wall of the cavernous sinus the ophthalmic nerve gives off (1) a small recurrent branch to the dura mater (n. tentorii), (2) communicating branches to the cavernous plexus of the sympathetic on the internal carotid artery, and (3) small communicating twigs to the trunks of the third, fourth, and sixth nerves.

In the sphenoidal fissure the nerve divides into three main branches—lachrymal, frontal, and nasal (Fig. 524).

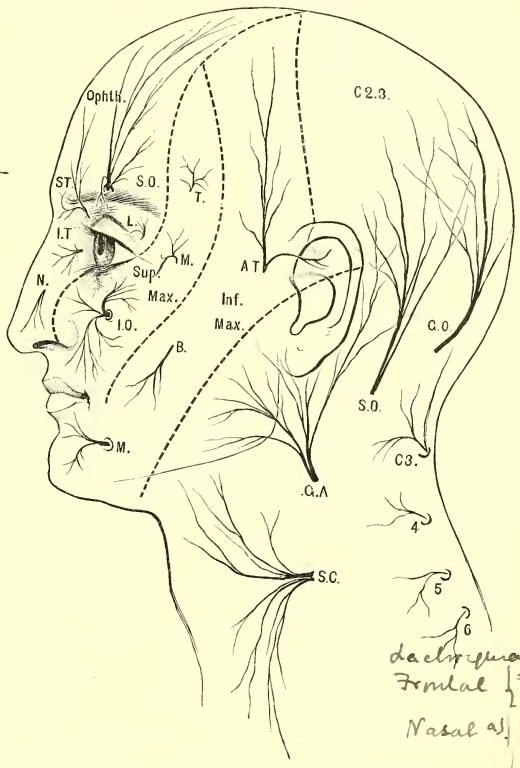


Fig. 523.—Distribution of Sensory Nerves to the Head and Neck.

Ophth, Ophthalmic division of the fifth nerve; St, Supra-trochlear branch; S.O, Supra-orbital branch; I.T, Infra-trochlear branch; L, Lachrymal branch; N, External nasal branch; Sup.Max, Superior maxillary division; T, Temporal branch; M, Malar branch; I.O, Infra-orbital branch; Inf.Max, Inferior maxillary division; A.T, Auriculo-temporal branch; B, Buccal branch; M, Mental branch; C2, 3, Branches of the second and third cervical nerves; G.O, Great occipital nerve; S.O, Small occipital nerve; G.A, Great auricular nerve; S.C, Superficial cervical nerve; C3, Least occipital nerve; 4, 5, 6, Posterior primary division of 4th, 5th, and 6th cervical nerves.

The **lachrymal nerve** (n. lacrymalis) enters the orbit through the outer angle of the sphenoidal fissure, above the orbital muscles. Passing forwards beneath the periosteum to the anterior part of the orbit, the nerve ends by supplying branches (*a*) to the lachrymal gland, (*b*) to the conjunctiva, and (*c*) to the skin of the outer canthus of the eye.

The lachrymal nerve *communicates* in the orbit with the orbital branch of the superior maxillary nerve, and on the face, by its terminal branches, with the temporal branches of the facial nerve (Fig. 523).

The **frontal nerve** (n. frontalis), entering the orbital cavity through the sphenoidal fissure, courses forwards above the ocular muscles, and divides at a variable point into two branches—a larger supra-orbital and a smaller supra-trochlear nerve. The **supra-orbital nerve** (n. supra-orbitalis) passes directly forwards, and leaves the orbit through the supra-orbital groove or foramen to reach the forehead. It gives off the following secondary branches: (1) the principal branches (rr. frontales) are distributed to the forehead and scalp, reaching backwards as far as the vertex; (2) small branches supply the upper eyelid; and (3) twigs are distributed to the frontal sinus. On the forehead the supra-orbital nerve communicates with the temporal branches of the facial nerve. The **supra-trochlear nerve** (n. supra-trochlearis) courses obliquely forwards and inwards over the tendon

of the superior oblique muscle to reach the inner side of the supra-orbital arch. Leaving the cavity of the orbit, the nerve is distributed to the skin of the mesial part of the forehead, the root of the nose, and the inner canthus of the eye.

It *communicates* with the infra-trochlear branch of the nasal nerve, either before or after leaving the orbital cavity.

The **nasal nerve** (n. naso-ciliaris) enters the orbit through the sphenoidal fissure, between the heads of the external rectus muscle, and between the two divisions of the third nerve (Fig. 520, p. 677). It crosses the orbital cavity obliquely to reach the anterior ethmoidal foramen, lying in its course below the superior rectus and superior oblique muscles, and above the optic nerve and internal rectus muscle. The nerve is transmitted through the anterior ethmoidal foramen into the cranial cavity, where it lies on the cribriform plate of the ethmoid bone. It enters the nasal cavity through the nasal fissure, and terminates by dividing into internal and external branches. The internal division supplies the mucous membrane over the upper and anterior part of the nasal septum (rr. mediales). The external branch, after supplying collateral offsets to the outer wall of the nose (rr. laterales), finally appears on the face between the nasal bone and lateral cartilage, and supplies branches to the skin of the lower part and tip of the nose.

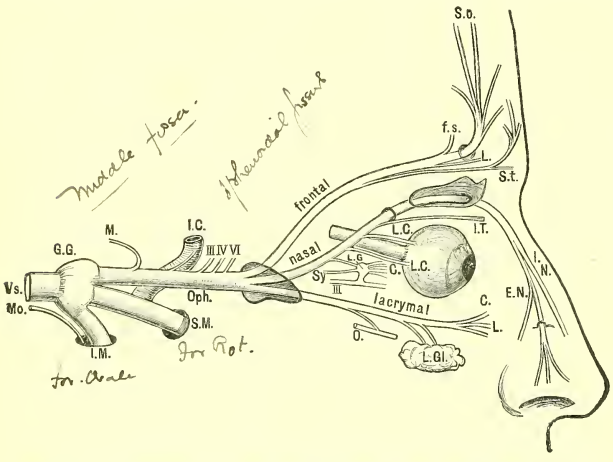


FIG. 524.—SCHEME OF THE DISTRIBUTION OF THE OPHTHALMIC NERVE.

Vs, Trigeminal nerve, afferent root; Mo, Efferent root; G.G, Gasserian ganglion; M, Meningeal branch; I.C, Branch to internal carotid artery; Oph, Ophthalmic nerve; S.M, Superior maxillary nerve; I.M, Inferior maxillary nerve; III, Communication to oculo-motor nerve; IV, To trochlear nerve; VI, To abducent nerve. Frontal nerve; f.s, Branches to frontal sinus; S.o, Supra-orbital nerve; S.t, Supra-trochlear nerve; L, Branches to upper eyelid. Nasal nerve; L.G, Long root to lenticular ganglion; Sy, Root from sympathetic (on carotid artery); III, Short root from motor oculi nerve; C, Short ciliary branches; L.C, Long ciliary nerves; I.T, Infra-trochlear nerve; E.N, External, and I.N, Internal nasal nerves. Lachrymal nerve; O, Orbital branch of superior maxillary nerve; L.Gl, Lachrymal gland; C, Conjunctival branch; L, Branch to eyelids and face.

The **branches** of the nasal nerve may be divided into three sets, arising (*a*) in the orbit, (*b*) in the nose, and (*c*) on the face.

In the orbit the branches are given off in three situations—external to, over, and internal to the optic nerve. (*a*) As the nasal nerve lies external to the optic nerve, it gives off the **long root of the ciliary ganglion** (radix longa). (*b*) As it crosses the optic nerve **two long ciliary branches** (nn. ciliaris longi) arise, and pass forwards alongside the optic nerve to the eyeball. (*c*) On the inner side of the optic nerve the **infra-trochlear nerve** (n. infra-trochlearis) arises, a slender branch which courses forward beneath the pulley of the superior oblique muscle to the front of the orbit. It ends on the face by supplying the skin of the root of the nose and the eyelids, and communicates either in the orbit or on the face with the supra-trochlear nerve. On the face it also communicates with infra-orbital branches of the facial nerve.

In the nose the **internal nasal branch** supplies the mucous membrane of the fore-part of the nasal septum; the **external nasal branch** supplies the fore-part of the outer wall of the nose.

On the face the terminal filaments of the nerve are distributed to the skin of the lower half and tip of the nose. The superficial terminal branch communicates with the infra-orbital branches of the facial nerve (Fig. 523).

The **ciliary** or **lenticular ganglion** (ganglion ciliare) is associated with the nasal branch of the ophthalmic nerve and with the lower division of the third nerve. It is a small reddish ganglion, placed between the external rectus muscle

and the optic nerve, and in front of the ophthalmic artery. Its *roots* are three in number: (1) **sensory** or long (radix longa), derived from the nasal branch of the ophthalmic nerve; (2) **motor** or short (radix brevis), derived from the inferior division of the third nerve; and (3) **sympathetic**, a slender filament from the cavernous plexus on the internal carotid artery, which may exist as an independent root or may be incorporated with the long root from the nasal nerve. The branches from the ganglion are twelve to fifteen **short ciliary nerves** (nn. ciliares breves), which pass to the eyeball in two groups above and below the optic nerve. They supply the coats of the eyeball, including the iris and ciliary muscles. *The circular fibres of the iris* and the *ciliary muscle* are innervated by the third nerve; *the radial fibres of the iris* by the sympathetic.

Superior Maxillary Division of the Fifth Nerve (n. maxillaris).—This large nerve courses forwards from its origin in the Gasserian ganglion through the middle fossa of the base of the skull, beneath the dura mater, and in relation to the lower part of the cavernous sinus (Fig. 520, p. 677). Passing through the foramen rotundum in the root of the pterygoid process, it traverses the spheno-maxillary fossa. It enters the orbit as the infra-orbital nerve, through the spheno-maxillary

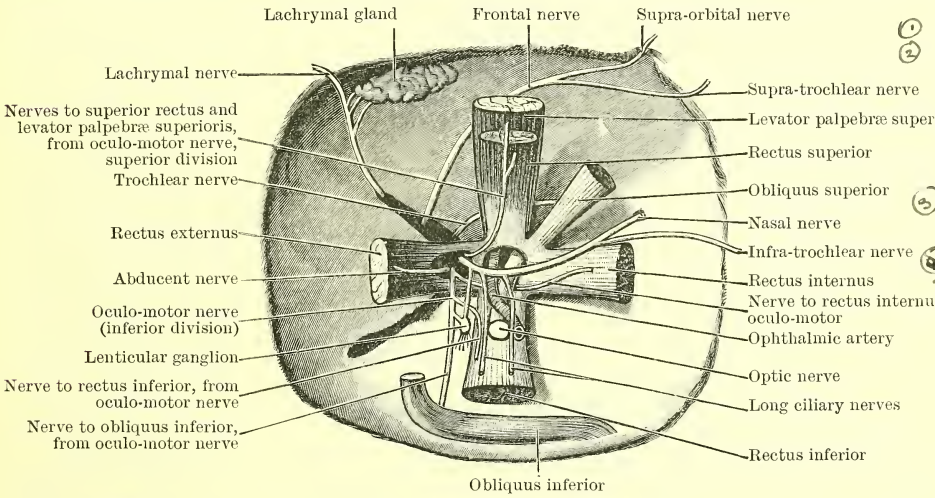


FIG. 525.—SCHEMATIC REPRESENTATION OF THE NERVES WHICH TRAVERSE THE CAVITY OF THE ORBIT.

fissure, and occupying successively the infra-orbital groove and canal, it finally appears on the face through the infra-orbital foramen (Fig. 526).

The branches and communications of this nerve occur (*a*) in the cavity of the cranium, (*b*) in the spheno-maxillary fossa, (*c*) in the infra-orbital canal, and (*d*) on the face.

(1) *In the cavity of the cranium* the nerve gives off a minute **recurrent branch** (n. meningeus) to the dura mater of the middle fossa of the base of the skull.

(2) *In the spheno-maxillary fossa* the nerve gives off—(1) two short thick **spheno-palatine nerves** (nn. spheno-palatini), the short or sensory roots of the spheno-palatine (Meckel's) ganglion. (2) A **posterior dental nerve**, which may be double (nn. alveolares superiores), descends through the pterygo-maxillary fissure to the outer side of the upper jaw, and proceeds forwards along the alveolar arch, in company with the posterior dental artery. It supplies the gum and the upper molar teeth by branches which perforate the bone to reach the alveoli. The nerve forms a fine plexus joined by the middle dental nerve before finally reaching the teeth. (3) A small **orbital branch** (n. zygomaticus) enters the orbital cavity through the spheno-maxillary fissure, and proceeding along the outer wall, communicates with the lachrymal nerve, and passes through the orbital canal in the malar bone, where it divides into malar and temporal branches. The **malar branch** (n. zygomatico-facialis) appears on the face, after traversing the malar bone, and supplies the skin over that bone. It communicates with the malar branches of the facial nerve. The **temporal branch** (n. zygomatico-temporalis) perforates the zygomatic

surface of the malar bone, and is distributed, after piercing the temporal fascia, to the skin over the fore-part of the temple. It communicates with the temporal branches of the facial nerve. It may be very minute, and not pass further than the temporal fascia, between the two layers of which it may form a communication with the facial nerve. (4) The **infra-orbital nerve** (n. infra-orbitalis) is the terminal branch of the superior maxillary nerve, which enters the orbit through the spheno-maxillary fissure and traverses the infra-orbital canal to reach the face.

In the infra-orbital canal the infra-orbital nerve supplies one and sometimes two branches to the teeth—the **middle** and **anterior dental nerves** (rr. alveolares superiores medius and anterior). The former may be only a secondary branch of the latter nerve, or they may arise independently from the infra-orbital nerve. However formed, the nerves descend in bony canals in the wall of the antrum of Highmore (to the lining of which branches are given), and reach the alveolar arch, where they form minute plexuses and supply the teeth (joining posteriorly with the branches of the posterior dental nerve). The anterior dental nerve supplies the incisor and canine teeth; the middle dental nerve supplies the premolar teeth.

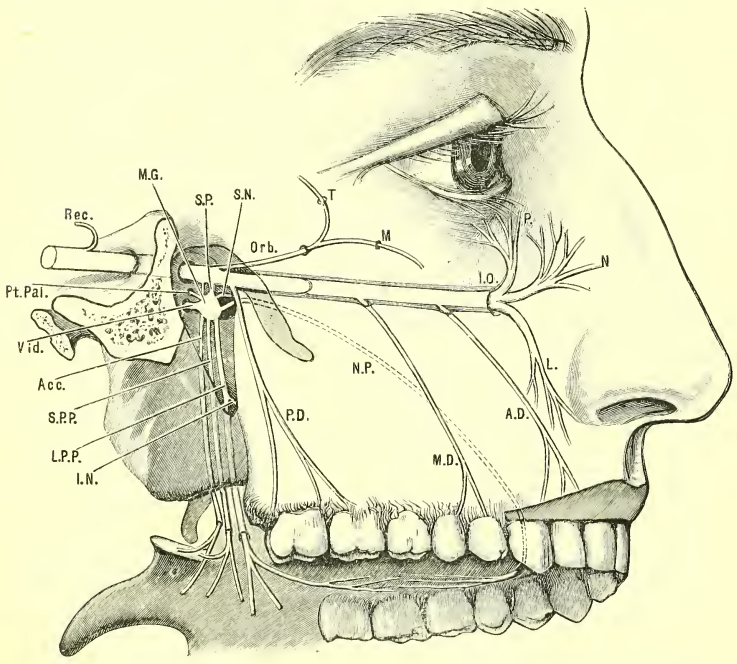


FIG. 526.—SCHEME OF THE COURSE AND DISTRIBUTION OF THE SUPERIOR MAXILLARY NERVE.

Rec, Recurrent branch in the middle fossa of the skull; M.G, Meckel's ganglion in the spheno-maxillary fossa; S.P, Spheno-palatine nerves; S.N, Superior nasal branch; Orb, Orbital nerve; T, Temporal, and M, Malar branches; I.O, Infra-orbital nerve, appearing on the face; P, Palpebral; N, Nasal, and L, Labial branches; A.D, Anterior dental branch; M.D, Middle dental branch; N.P, Naso-palatine nerve; P.D, Posterior dental branch; I.N, Inferior nasal branch; L.P.P, Large posterior palatine nerve; S.P.P, Small posterior palatine nerve; Acc, Accessory posterior palatine nerve; Vid, Vidian nerve; Pt.Pal, Pterygo-palatine branch.

After emerging on the face from the infra-orbital foramen, the infra-orbital nerve divides into a number of radiating branches arranged in three sets—(*a*) **palpebral**, for the lower eyelid; (*b*) **nasal**, for the skin of the side of the nose; and (*c*) **labial**, for the cheek and upper lip. These branches form communications with the infra-orbital branches of the facial nerve, and give rise to the *infra-orbital plexus* (Fig. 523, p. 679).

The **spheno-palatine** or **Meckel's ganglion** (g. spheno-palatinum) occupies the upper part of the spheno-maxillary fossa. It is a small reddish-gray ganglion, suspended from the superior maxillary nerve by the two **spheno-palatine branches** which constitute its sensory roots. The **motor** and **sympathetic roots** of the ganglion are derived from the **vidian nerve.** This nerve is formed in the cavity of the skull upon the cartilage filling up the foramen lacerum medium, by the union of the *great superficial petrosal nerve* from the geniculate ganglion of the facial nerve (emerging from the temporal bone through the hiatus Fallopii) with the *great deep petrosal nerve,* a branch of the carotid plexus of the sympathetic on the internal carotid artery. The vidian nerve passes through the vidian canal to the spheno-maxillary fossa, where it ends in Meckel's ganglion.

The **branches from the ganglion** are seven in number. (*a*) The **pterygo-palatine** or **pharyngeal** branch passes backwards through the pterygo-palatine canal to supply the mucous membrane of the roof of the pharynx.

(*b*) The **posterior palatine nerves**, three in number, are directed downwards to the palate through the posterior palatine canals. The **large posterior palatine nerve** emerges on the under surface of the palate through the large posterior palatine canal, and at once separates into numerous branches for the supply of the mucous membrane of the soft and the hard palate. Its anterior filaments communicate with branches of the naso-palatine nerve. The main nerve gives off, as it lies in the posterior palatine canal, a small **inferior nasal nerve** which enters the nasal cavity and supplies the mucous membrane of the lower part of the outer wall of the nose. The **small posterior palatine nerve** descends through the small posterior palatine canal, and, piercing the tuberosity of the palate bone, is distributed to the mucous membrane of the soft palate, uvula, and tonsil. It possibly conveys motor fibres to the levator palati and azygos uvulæ muscles. The **accessory posterior palatine nerves** are one or more small twigs which pass through accessory posterior palatine canals, and supply branches to the mucous membrane of the tonsil, soft palate, and uvula.

(*c*) The branches directed inwards from Meckel's ganglion enter the nasal cavity through the spheno-palatine foramen. They are two in number—the superior nasal and the naso-palatine. The **superior nasal nerve** is a small nerve destined for the mucous membrane of the upper and back part of the outer wall of the nose. The **naso-palatine nerve**, after passing through the spheno-palatine foramen, crosses the roof of the nose, and extends obliquely downwards and forwards along the nasal septum, grooving the vomer in its course, to reach the incisor foramen near the front of the hard palate. The nerves pass through the subordinate mesial foramina (of Scarpa), the left nerve in front of the right. In the incisor foramen the two nerves communicate together. They then turn backwards and supply the mucous membrane of the hard palate. They communicate posteriorly with terminal filaments of the large posterior palatine nerves. In its course through the nasal cavity the naso-palatine nerve furnishes collateral branches to the mucous membrane of the roof and septum of the nose (Fig. 518, p. 676).

(*d*) The **orbital branches**, one or more minute branches, pass upwards to the periosteum of the orbit from Meckel's ganglion.

Inferior Maxillary Nerve (n. mandibularis).—The inferior maxillary nerve is formed by the union of two roots: a large **sensory root**, from the Gasserian ganglion, and the small **motor root** of the trigeminal nerve, which is wholly incorporated with this trunk. The two roots pass together beneath the dura mater of the middle fossa of the base of the skull to the foramen ovale, through which they emerge into the pterygoid region. Outside the skull they combine to form a single trunk, which soon separates into anterior and posterior divisions.

At its emergence from the skull the nerve is deeply placed beneath the middle of the zygomatic arch, and is concealed by the ramus of the lower jaw, and by the temporal, masseter, and external pterygoid muscles.

The branches of the inferior maxillary nerve may be divided into two series—(1) those derived from the undivided nerve, and (2) those derived from the terminal divisions of the nerve.

The branches of the undivided nerve are two in number. (*a*) A small **recurrent branch** (n. spinosus) arises just outside the skull, and accompanying the middle meningeal artery through the foramen spinosum, supplies the dura mater. (*b*) In the pterygoid region a small branch arises for the supply of the **internal pterygoid muscle.** This nerve forms a connexion with the otic ganglion.

The terminal divisions of the nerve are a small anterior and a large posterior trunk.

The small **anterior trunk** passes downwards and forwards beneath the external pterygoid muscle, and separates into the following branches:—(1) A branch for the external pterygoid muscle (n. pterygoideus externus), which supplies it on its deep surface; (2) a branch to the masseter muscle (n. massetericus), which passes over the upper border of the external pterygoid and through the sigmoid notch of the lower jaw; (3) and (4) two branches to the temporal muscle (nn. temporales pro-

fundi, anterior et posterior), which also ascend above the external pterygoid muscle; and (5) the **buccal nerve** (n. buccinatorius), which passes obliquely forwards between the two heads of the external pterygoid to reach the buccinator muscle. This nerve is sensory, and its fibres are in part distributed to the skin of the cheek (communicating with buccal branches of the facial nerve); they are also in part distributed to the mucous membrane of the inside of the mouth, to reach which they pierce the fibres of the buccinator muscle. The buccal nerve usually supplies a third branch to the temporal muscle, after emerging between the two heads of the external pterygoid muscle (Fig. 523, p. 679).

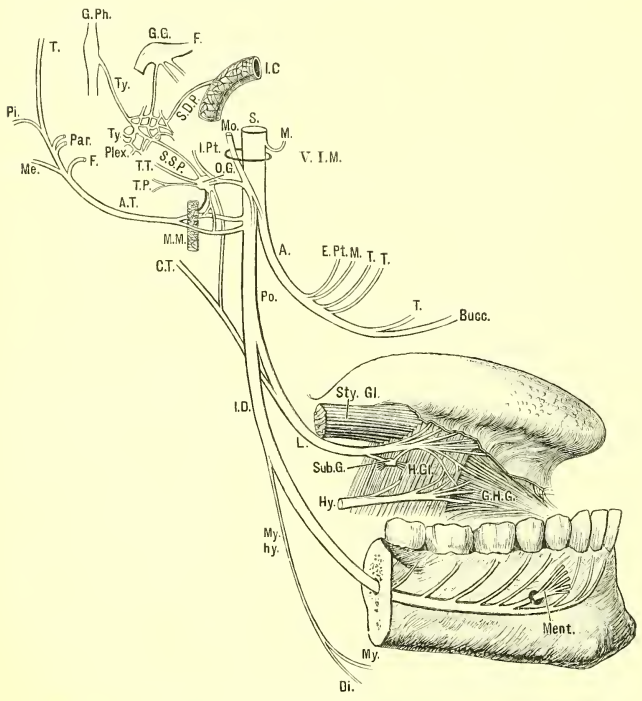


FIG. 527.—SCHEME OF THE DISTRIBUTION OF THE INFERIOR MAXILLARY NERVE.

V.I.M, Inferior maxillary nerve; S, Afferent, and Mo, Efferent roots; M, Meningeal branch; O.G, Otic ganglion; I.Pt, Nerve to internal pterygoid; S.S.P, Small superficial petrosal nerve; T.T, Nerves to tensor tympani, and T.P, Tensor palati; Ty.Plex, Tympanic plexus; I.C, Internal carotid artery; S.D.P, Small deep petrosal nerve; G.G, Geniculate ganglion; F, Facial nerve; Ty, Tympanic branch; G.Ph, Glosso-pharyngeal nerve; M.M, Middle meningeal artery; A.T, Auriculo-temporal nerve; F, Communication with facial nerve; Par, Nerve to parotid gland; Me, Branch to meatus of ear; Pi, Branch to pinna; T, Temporal branch; A, Anterior division of inferior maxillary nerve; E.Pt, Nerves to external pterygoid; M, Masseter; T.T.T, Temporal, and Bucc, Buccinator muscles; Po, Posterior division of inferior maxillary nerve; L, Lingual nerve; C.T, Chorda tympani nerve; Sub.G, Sub-maxillary ganglion; Hy, Hypoglossal nerve; I.D, Inferior dental nerve; My.hy, Mylohyoid nerve; My, Nerve to mylohyoid; Di, Nerve to digastric (anterior belly); Ment., Mental Branch; Sty.Gl, Stylo-glossus; H.Gl, Hyoglossus; G.H.G, Genio-hyoglossus muscles.

The large **posterior trunk** extends downwards a short way beneath the external pterygoid muscle. After giving off by two roots the auriculo-temporal nerve, it ends by dividing into two, the lingual and the inferior dental nerves.

The **auriculo-temporal nerve** (n. auriculo-temporalis) is formed by the union of two roots which embrace the middle meningeal artery. The nerve passes backwards beneath the external pterygoid muscle and between the internal lateral ligament and the neck of the lower jaw. Entering the substance of the parotid gland, it is directed upwards to the temple over the zygoma in company with the temporal artery. It is finally distributed as a cutaneous nerve of the temple and scalp, and reaches almost to the vertex of the skull.

The auriculo-temporal nerve gives off the following branches:—(1) A small branch to the temporo-maxillary articulation. (2) Branches to the parotid gland. (3) A twig for the supply of the skin of the external auditory meatus (and membrana tympani). (4) Branches to the upper half of the pinna on its outer aspect. (5) Terminal branches to the skin of the temple and scalp.

It has the following **communications** with other nerves:—(1) Important communications are effected by the roots of the nerve, which are separately joined by small branches from the otic ganglion. (2) The parotid branches of the nerve are connected with branches of the facial nerve in the substance of the gland. (3) The temporal branch of the nerve is in communication superficially with the temporal branches of the facial nerve.

The **lingual nerve** (n. lingualis) is the smaller of the two terminal branches

of the posterior division of the inferior maxillary nerve. It proceeds downwards in front of the inferior dental nerve, beneath the external pterygoid muscle, to its lower border. After passing between the internal pterygoid muscle, and the ramus of the lower jaw, it crosses beneath the mucous membrane of the floor of the mouth in the interval between the mylohyoid and hyoglossus muscles and beneath the duct of the submaxillary gland. It sweeps forwards and inwards to the side of the tongue, to the mucous membrane over the anterior two-thirds of which it is distributed.

Two nerves communicate with the lingual nerve in its course to the tongue :—(1) The **chorda tympani branch** of the facial nerve joins it beneath the external pterygoid muscle, and is incorporated with it in its distribution to the tongue. (2) The **hypoglossal nerve** forms larger or smaller loops of communication with the lingual nerve as they course forwards together over the hyoglossus muscle.

Besides supplying the aforesaid branches to the mucous membrane over the sides and dorsum of the tongue in its anterior two-thirds, the lingual nerve supplies the mucous membrane of the outer wall and floor of the mouth. It also assists, along with the chorda tympani nerve, in forming the roots of the submaxillary ganglion.

The **submaxillary ganglion** (ganglion submaxillare) is a minute reddish ganglion placed on the hyoglossus muscle, between the lingual nerve and the duct of the submaxillary gland. It is suspended from the former by two trunks, consisting for the most part of fibres of the lingual and chorda tympani nerves which at this point become separated from the lingual nerve and incorporated with the ganglion. The **roots** of the ganglion are—(1) an afferent root, derived from the lingual nerve ; (2) an efferent root, derived from the chorda tympani ; and (3) a sympathetic root, from the sympathetic plexus upon the facial artery.

The **branches from the ganglion** are distributed to the submaxillary gland and Wharton's duct, and by fibres which become reunited with the trunk of the lingual nerve, to the sublingual gland.

The **inferior dental nerve** (n. alveolaris inferior) is larger than the lingual nerve. It passes from beneath the lower border of the external pterygoid muscle to reach the interval between the ramus and internal lateral ligament of the lower jaw. Entering the inferior dental canal through the inferior dental foramen, it traverses the substance of the ramus and body of the lower jaw, distributing branches in its course to the teeth. A fine plexus is formed by the dental branches before they finally supply the teeth.

Branches and Communications.—(1) The **mylohyoid nerve** is a small branch arising just before the inferior dental nerve passes through the inferior dental foramen. Grooving the ramus of the jaw in its course, it descends into the submaxillary triangle on the superficial aspect of the mylohyoid muscle. Concealed in this situation by the submaxillary gland and the facial artery, it is distributed to the mylohyoid and anterior belly of the digastric muscles. (2) The **mental branch** of the inferior dental nerve is a trunk of considerable size arising from the main nerve in the inferior dental canal. It emerges from the lower jaw through the mental foramen, and is distributed by many branches to the chin and lower lip. It communicates beneath the facial muscles with the supra-mandibular branches of the facial nerve (Fig. 523, p. 679). (3) The **incisor branch** is the terminal part of the inferior dental nerve remaining after the origin of the mental branch. It supplies the incisor and canine teeth.

The **otic ganglion** (g. oticum) is situated beneath the inferior maxillary nerve just below the foramen ovale. Like the other ganglia described above, it possesses three roots :—(1) A *motor root,* derived from the nerve to the internal pterygoid muscle ; (2) a *sensory root,* formed by the *small superficial petrosal nerve* from the tympanic plexus (through which communications are effected with the tympanic branch of the glosso-pharyngeal nerve, and a branch from the geniculate ganglion of the facial nerve); (3) a *sympathetic root,* from the plexus on the middle meningeal artery (Fig. 527).

Five branches arise from the ganglion—three communicating and two motor branches. The three **communicating nerves** are fine branches which join respectively

the vidian nerve, the roots of the auriculo-temporal, and the chorda tympani nerve. The two **motor nerves** supply the tensor tympani and tensor palati muscles.

Summary.—The trigeminal, the largest and most complex of the cranial nerves, is (1) the chief sensory nerve for the face, the anterior half of the scalp, the orbit and eyeball, the nose and nasal cavity, the lips, teeth, mouth, and two-thirds of the tongue; (2) the motor fibres of the nerve supply the muscles of mastication, the mylohyoid and anterior belly of the digastric, possibly the levator palati and azygos uvulæ (through Meckel's ganglion), and the tensor tympani and tensor palati muscles (through the otic ganglion); (3) through the ganglia placed on the three divisions of the nerve, not only are important organs, areas, and muscles innervated, but communications are also effected with the sympathetic system, with the third nerve (lenticular ganglion), facial nerve (spheno-palatine and otic ganglia), and glosso-pharyngeal nerve (otic ganglion).

In its distribution to the skin of the face the branches of the fifth nerve present two striking peculiarities:—(1) While the branches to the skin reach the surface at many points and in diverse ways, the three main divisions are severally, by their branches, responsible for the supply of three clearly demarcated cutaneous areas (Fig. 523, p. 679). (2) By numerous communications with the facial nerve, sensory fibres are given to the muscles of expression supplied by the facial nerve.

The Sixth or Abducent Nerve.

The abducent nerve (n. abducens) issues from the brain at the lower border of the pons Varolii, just above the pyramid of the medulla oblongata (for deep origin, see p. 524). It is directed forwards, and pierces the dura mater in the posterior fossa of the base of the skull alongside the dorsum sellæ (Fig. 522, p. 678). It then occupies the inner wall of the cavernous sinus and is placed on the outer side of the internal carotid artery. It passes through the sphenoidal fissure below the third and nasal nerves and between the two heads of the external rectus muscle (Fig. 520, p. 677). In the cavity of the orbit it supplies the external rectus muscle on its inner (ocular) surface.

Communications.—In the wall of the cavernous sinus the sixth nerve receives two communicating filaments:—(1) From the carotid plexus of the sympathetic, and (2) from the ophthalmic division of the trigeminal nerve.

The Seventh or Facial Nerve.

The facial nerve (n. facialis) emerges from the brain at the posterior border of the pons Varolii, below the trigeminal nerve and internal to the auditory nerve (for deep origin, see p. 522). Between it and the latter nerve is the minute **pars intermedia** of Wrisberg (Fig. 517, p. 675). The nerve passes outwards through the internal auditory meatus, courses through the aqueduct of Fallopius in the petrous portion of the temporal bone, emerges in the base of the skull by the stylo-mastoid foramen, and passes forwards through the parotid gland to supply the muscles of the face. *In the internal auditory meatus* the nerve is placed upon the auditory nerve, the *pars intermedia* intervening. *In the aqueduct of Fallopius* the nerve first passes backwards on the inner side of the tympanum, and then downwards behind the tympanum, in the inner wall of the tympanic antrum. *In the parotid gland* the nerve crosses superficially the external carotid artery and the temporo-maxillary vein. *On the face* its branches radiate from the anterior border of the parotid gland and enter the deep surface of the facial muscles.

Branches and Communications.—(i.) *In the internal auditory meatus* the *pars intermedia* (n. intermedius), lying between the facial and auditory, sends communicating branches to both nerves. The branch to the auditory nerve probably separates from it again to join the geniculate ganglion of the facial nerve.

(ii.) *In the aqueduct of Fallopius* the **geniculate ganglion** (g. geniculi) is formed at the point where the facial nerve bends backwards (geniculum n. facialis). It is an oval swelling on the nerve, and is joined by a branch from the upper (vestibular) trunk of the auditory nerve, by which it probably receives fibres of the *pars intermedia*. From the ganglion three small nerves arise:—(1) The **large superficial petrosal nerve** passes forwards through the hiatus Fallopii to the middle fossa of the base of the skull. On the upper surface of the foramen lacerum medium it is

joined by the **great deep petrosal nerve** from the sympathetic plexus on the internal carotid artery to form the **vidian nerve**, which, after traversing the vidian canal, ends in Meckel's ganglion. (2) A minute nerve pierces the temporal bone and joins the tympanic branch of the glosso-pharyngeal in the substance of the bone. By their union the **small superficial petrosal nerve** is formed, which pierces the temporal bone and ends in the otic ganglion. (3) The **external superficial petrosal nerve** is a minute inconstant branch which joins the sympathetic plexus on the middle meningeal artery.

In the course of the facial nerve in the lower part of the aqueduct of Fallopius, behind the tympanum, three branches arise—(1) The small nerve to the **stapedius muscle**, which passes forwards to the tympanum. (2) The **chorda tympani nerve** (probably associated with the *pars intermedia*), which enters the tympanic cavity through the *iter chordæ posterius*, passes over the membrana tympani and the handle of the malleus, and leaves the cavity through the *iter chordæ anterius* to reach the pterygoid region. Beneath the external pterygoid muscle it becomes incorporated with the lingual branch of the inferior maxillary nerve, and in its further course is inseparable from that nerve. It supplies a root to the sub-maxillary ganglion, and is finally distributed (probably as a nerve of taste) to the side and dorsum of the tongue in its anterior two-thirds. The chorda tympani nerve receives beneath the external pterygoid muscle a fine communication from the otic ganglion. (3) Before it leaves the aqueduct of Fallopius a fine **communicating branch** arises from the facial nerve to join the auricular branch of the pneumogastric nerve.

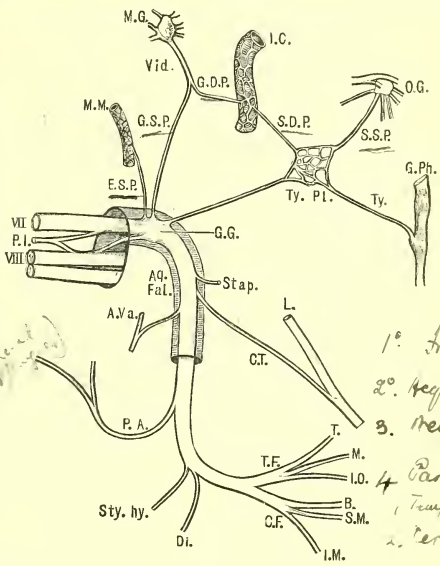


FIG. 528.—THE FACIAL NERVE WITH ITS BRANCHES AND COMMUNICATIONS IN THE AQUEDUCT OF FALLOPIUS.

VII, Facial nerve; P.I, Pars intermedia; VIII, Auditory nerve; Aq.Fal, Aqueduct of Fallopius; G.G, Geniculate ganglion; E.S.P, External superficial petrosal nerve; M.M, Middle meningeal artery; G.S.P, Great superficial petrosal nerve: G.P.D, Great deep petrosal nerve; I.C, Internal carotid artery; Vid, Vidian nerve; M.G, Meckel's ganglion; Ty.Pl, Tympanic plexus; S.D.P, Small deep petrosal nerve; G.Ph, Glosso-pharyngeal nerve; Ty, Tympanic branch; S.S.P, Small superficial petrosal nerve; O.G, Otic ganglion; Stap, Nerve to stapedius; C.T, Chorda tympani nerve; L, Lingual nerve; A.Va, Communication with auricular branch of vagus; P.A, Posterior auricular nerve; Sty.hy, Nerve to stylo-hyoid; Di, Nerve to digastric (posterior belly); T.F, Temporo-facial division; C.F, Cervico-facial division; T. Temporal; M, Malar; I.O, Infra-orbital; B. Buccal; S.M, Supra-mandibular, and I.M, Infra-mandibular branches.

(iii.) *In the neck* the facial nerve gives off three muscular branches: (1) and (2) small branches supply the stylo-hyoid and the posterior belly of the digastric, the latter nerve sometimes communicating with the glosso-pharyngeal. (3) The **posterior auricular nerve** bends backwards and upwards over the anterior border of the mastoid process along with the posterior auricular artery. It divides into two branches—an *auricular branch* for the retrahens aurem and the intrinsic muscles of the pinna, and an *occipital branch* for the posterior belly of the occipito-frontalis muscle. The posterior auricular nerve communicates with the great auricular, small occipital, and auricular branch of the pneumogastric nerves in its course.

(iv.) *In the parotid gland* the facial nerve spreads out in an irregular series of branches (**pes anserinus**), indefinitely divided into a temporo-facial and a cervico-facial division. Communications occur in the substance of the gland between the main trunks and the great auricular and auriculo-temporal nerves.

The **temporo-facial division** gives off three series of subordinate branches which radiate forwards and upwards from the parotid gland.

1. The **temporal branches** are of large size, and, sweeping out of the parotid gland over the zygomatic arch, are distributed to the orbicularis palpebrarum, frontalis, corrugator supercilii, attrahens, and attollens aurem. The temporal branches com-

municate in their course with the auriculo-temporal, temporal (of the superior maxillary), lachrymal, and supra-orbital branches of the trigeminal nerve.

2. The **malar branches** are small, and sometimes are inseparable from the temporal or infra-orbital nerves. Extending forwards across the malar bone, they supply the orbicularis palpebrarum and zygomatic muscles, and communicate with the malar branch of the superior maxillary nerve.

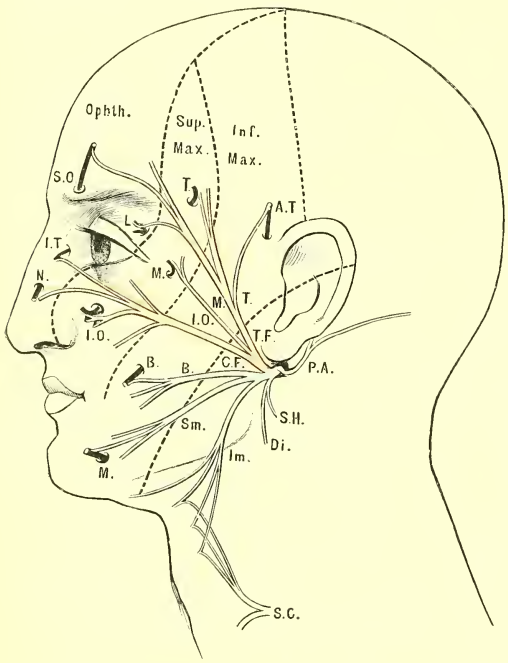


FIG. 529. — DISTRIBUTION OF FACIAL NERVE OUTSIDE THE SKULL, AND COMMUNICATIONS WITH TRIGEMINAL NERVE ON THE FACE.

Facial nerve. — P.A, Posterior auricular nerve; S.H, Nerve to stylo-hyoid; Di, Nerve to digastric (posterior belly); T.F, Temporo-facial division; T, Temporal; M, Malar; I.O, Infra-orbital branches; C.F, Cervico-facial division; B, Buccal; Sm, Supra-mandibular; Im, Infra-mandibular branches.

Trigeminal nerve. — Ophth, Ophthalmic division; S.O, Supra-orbital; I.T, Infra-trochlear; N, External nasal; L, Lachrymal branches. Sup. Max, Superior maxillary division; T, Temporal; M, Malar; I.O, Infra-orbital branches. Inf. Max, Inferior maxillary division; A.T, Auriculo-temporal; B, Buccal; M, Mental branches; S.C, Superficial cervical nerve.

3. The **infra-orbital branches** are of considerable size. Passing forwards over the masseter muscle in company with Stenson's duct, they supply the orbicularis palpebrarum, the zygomatici, buccinator, and the muscles of the nose and upper lip. The **infra-orbital plexus** is formed by the union of these nerves with the infra-orbital branch of the superior maxillary nerve below the lower eyelid. Smaller communications occur with the infra-trochlear and nasal nerves on the side of the nose.

The **cervico-facial division** of the facial nerve also supplies three series of secondary branches.

1. The **buccal branch** (or branches) extends forwards to the angle of the mouth to supply the muscles converging to the mouth, including the buccinator. It communicates with the buccal branch of the inferior maxillary nerve in front of the anterior border of the masseter muscle.

2. The **supra-mandibular branch** passes along the lower jaw to the interval between the lower lip and chin, and supplies the depressor anguli oris, depressor labii inferioris, and orbicularis oris. It communicates with the mental branch of the inferior dental nerve.

3. The **infra-mandibular branch** emerges from the parotid gland near its lower end, and sweeps forwards below the angle of the jaw to the front of the neck. It supplies the platysma myoides, and forms loops of communication with the superficial cervical nerve from the cervical plexus.

THE EIGHTH OR AUDITORY NERVE.

The auditory nerve (n. acusticus) arises from the brain by two roots, mesial and lateral. The **mesial root** (radix vestibularis) emerges between the olive and the restiform body. The **lateral root** (radix cochlearis), continuous through the cochlear nucleus with the striæ acusticæ of the fourth ventricle, winds round the outer side of the restiform body (for deep connexions, see p. 519). The two roots become incorporated to form the trunk of the nerve, which is attached to the brain on the outer side of the facial nerve and pars intermedia at the posterior border of the pons Varolii (Fig. 517, p. 675).

The nerve extends outwards through the internal auditory meatus, lying beneath the facial nerve and pars intermedia (Fig. 522, p. 678). In the meatus its two component parts separate from one another, forming a superior or vestibular trunk continuous with the mesial root, and an inferior or cochlear trunk continuous with

the lateral root. These trunks again subdivide, and piercing the lamina cribrosa, supply the several parts of the labyrinth.

The **superior** or **vestibular trunk** (n. vestibuli) in the internal auditory meatus usually receives fibres from the *pars intermedia*, and gives off a communicating branch

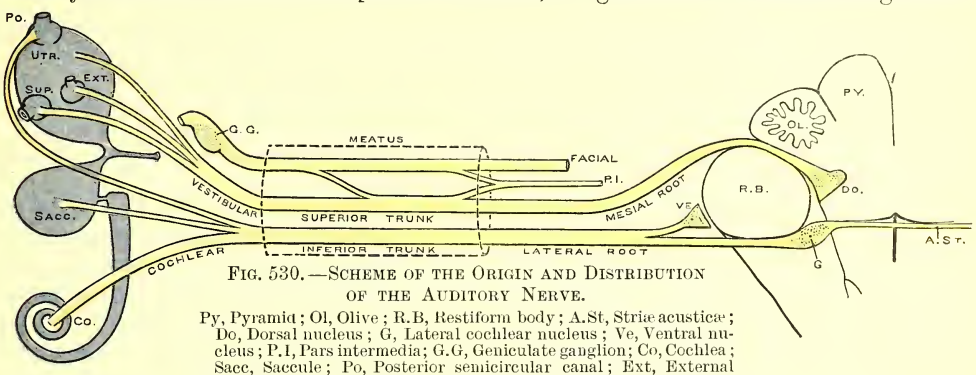


FIG. 530.—SCHEME OF THE ORIGIN AND DISTRIBUTION OF THE AUDITORY NERVE.

Py, Pyramid; Ol, Olive; R.B, Restiform body; A.St, Striæ acusticæ; Do, Dorsal nucleus; G, Lateral cochlear nucleus; Ve, Ventral nucleus; P.I, Pars intermedia; G.G, Geniculate ganglion; Co, Cochlea; Sacc, Saccule; Po, Posterior semicircular canal; Ext, External semicircular canal; Sup, Superior semicircular canal; Utr, Utricle.

to the geniculate ganglion of the facial nerve. It then separates into three terminal branches which pierce the lamina cribrosa, and supply (1) the macula acustica of the **utricle** and the ampullæ of (2) the **superior** and (3) **external semicircular canals.**

The **inferior** or **cochlear trunk** (n. cochleæ) gives off branches (1) to the macula acustica of the **saccule**, (2) to the ampulla of the **posterior semicircular canal,** and (3) is continued through the lamina cribrosa to the labyrinth as the **cochlear nerve**, which is distributed through the modiolus and osseous spiral lamina to the organ of Corti in the cochlea.

Both the vestibular and cochlear nerves contain among their fibres collections of nerve cells, forming in each nerve a distinct ganglion—the **vestibular ganglion** (g. vestibulare) on the vestibular trunk, and the **spiral ganglion of the cochlea** (g. spirale) on the cochlear trunk.

THE NINTH OR GLOSSO-PHARYNGEAL NERVE.

The glosso-pharyngeal nerve (n. glosso-pharyngeus) (Fig. 517, p. 675) arises from the brain by five or six fine radicles which emerge from the medulla oblongata between the olive and the restiform body, close to the facial nerve above, and in series with the roots of the pneumogastric nerve below (for deep connexions, see p. 517). The rootlets combine to form a nerve which extends outwards to the jugular foramen, through which it passes, along with the pneumogastric and spinal accessory nerves, but enveloped in a separate sheath of dura mater (Fig. 522, p. 678). Reaching the neck, the nerve arches downwards and forwards to the interval between the hyoid bone and the lower jaw. It lies at first between the internal carotid artery and the internal jugular vein, and then between the internal and external carotid arteries, in its course to the side of the pharynx. It sweeps round the stylo-pharyngeus muscle and the stylo-hyoid ligament, and disappears beneath the hyoglossus muscle, to reach its termination in the tongue.

The branches of the nerve may be classified in three series according to their origin—(i.) in the jugular foramen; (ii.) in the neck; (iii.) in relation to the tongue.

In the jugular foramen there are two enlargements upon the trunk of the nerve —the jugular and petrous ganglia. The **jugular ganglion** (g. superius) is small, does not implicate the whole width of the nerve, and may be fused with the petrous ganglion, or even absent altogether. No branches arise from it.

The **petrous ganglion** (g. petrosum) is distinct and constant. It is placed upon the nerve at the lower part of its course through the jugular foramen.

Branches and Communications of the Petrous Ganglion.—The **tympanic branch** (n. tympanicus, Jacobson's nerve) is the most important offset from this ganglion. It passes through a small canal in the bridge of bone between the jugular foramen and the carotid canal to reach the cavity of the tympanum, where it breaks up into branches, to form, along with branches from the carotid plexus of the sympathetic on the internal carotid artery (**small deep petrosal nerve**), the **tympanic plexus** for the supply of the mucous lining of the tympanum, mastoid cells, and Eustachian tube (Fig. 528,

p. 687). The fibres of the tympanic branch of the glosso-pharyngeal nerve become reunited to form, by their union with a small nerve from the geniculate ganglion of the facial nerve, the **small superficial petrosal nerve** in the substance of the temporal bone. This passes forwards through the temporal bone, and eventually joins the otic ganglion.

Besides forming the tympanic branch, the petrous ganglion of the glosso-pharyngeal nerve communicates with three other nerves—(1) with the superior cervical ganglion of the sympathetic; (2) with the auricular branch of the pneumogastric; and (3) sometimes with the ganglion of the root of the pneumogastric.

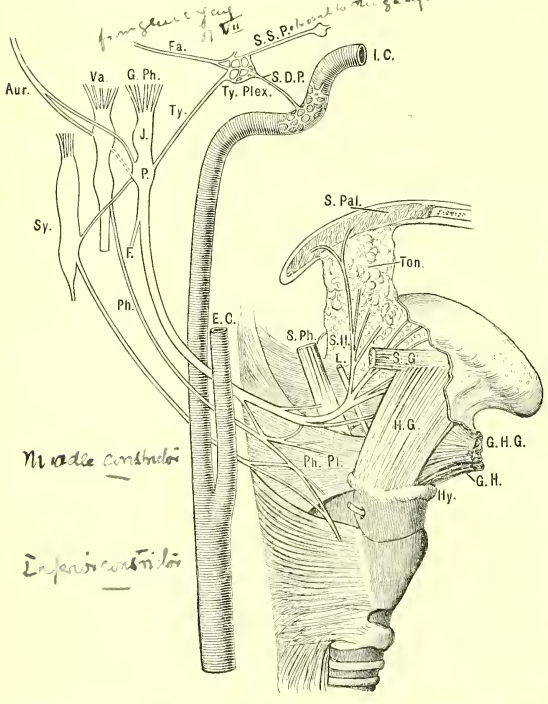


FIG. 531.—SCHEME OF THE DISTRIBUTION OF THE GLOSSO-PHARYNGEAL NERVE.

G.Ph, Glosso-pharyngeal nerve; J, Jugular, and P, Petrous ganglia; Ty, Tympanic branch (Jacobson's nerve); Ty.Plex., Tympanic plexus; Fa, Root from geniculate ganglion of facial nerve; S.S.P, Small superficial petrosal nerve to the otic ganglion; S.D.P, Small deep petrosal nerve; I.C, Internal carotid artery; Va, Pneumogastric nerve; Aur., Auricular branch (Arnold's nerve); Sy., Superior cervical sympathetic ganglion; F, Communicating branch to facial nerve; Ph, Pharyngeal branch of vagus; E.C, External carotid artery; Ph.Pl, Pharyngeal plexus; S.Ph, Stylo-pharyngeus muscle; S.H.L, Stylo-hyoid ligament; H.G, Hyo-glossus; S.G, Stylo-glossus; Ton, Tonsil; S. Pal., Soft palate; G.H.G, Genio-hyoglossus; G.H, Genio-hyoid; Hy, Hyoid bone.

In the neck the glosso-pharyngeal nerve gives off two branches. (1) As it crosses over the **stylo-pharyngeus muscle** it supplies the nerve to that muscle, which sends fibres through it to reach the mucous membrane of the pharynx. (2) The **pharyngeal branches** of the nerve supply the mucous membrane of the pharynx directly after piercing the superior constrictor muscle, and indirectly after joining, along with the pharyngeal offsets from the pneumogastric and the superior cervical ganglion of the sympathetic, in the formation of the **pharyngeal plexus**.

The **terminal branches** of the nerve supply the mucous membrane of the tongue and adjacent parts. A **tonsillitic branch** forms a plexus (circulus tonsillaris) to supply the mucous membrane covering the tonsil, the adjacent part of the soft palate, and the pillars of the fauces. **Lingual branches** supply the mucous membrane of the dorsal third and lateral half of the tongue, extending backwards to the glosso-epiglottidean folds and the front of the epiglottis.

THE TENTH OR PNEUMOGASTRIC NERVE.

The pneumogastric or vagus nerve (n. vagus) arises from the brain by numerous radicles attached to the front of the restiform body of the medulla oblongata, in series with the glosso-pharyngeal nerve above and the spinal accessory nerve below it (for deep connexions, see p. 517). Uniting to form a single trunk, the roots of the nerve pass outwards to the jugular foramen, through which they emerge into the neck.

In the jugular foramen the nerve occupies the same sheath of dura mater as the spinal accessory nerve, and is placed behind the glosso-pharyngeal nerve. Two ganglia are present on the trunk in this situation. The higher and smaller is the **ganglion of the root** (g. jugulare); the lower and larger is the **ganglion of the trunk** of the nerve (g. nodosum).

In the neck the pneumogastric nerve pursues a vertical course in front of the spinal column. It occupies the carotid sheath, lying between and behind the internal and common carotid arteries and the internal jugular vein. It enters the

thorax behind the large veins : *on the right side,* after crossing over the subclavian artery ; *on the left side,* in the interval between the left common carotid and subclavian arteries.

In the thorax the nerves occupy the superior and posterior mediastinal spaces, and their relations are different on the two sides. (*a*) *In the superior mediastinum* the *right nerve* continues its course alongside the innominate artery and the trachea, and behind the right innominate vein and superior vena cava, to the back of the root of the lung. The *left nerve* courses downwards between the left common carotid and subclavian arteries, and behind the left innominate vein and the phrenic nerve. It passes over the aortic arch, and then proceeds to the back of the root of the left lung. (*b*) *In the posterior mediastinum* the pneumogastric nerves are concerned in the formation of two great plexuses—the pulmonary and the œsophageal. Behind the root of each lung the nerve breaks up to form the large **posterior pulmonary plexus**, from the lower end of which two nerves emerge on each side. These nerves on the right side pass obliquely over the vena azygos major; on the left side they cross the thoracic aorta. Both series reach the œsophagus, and divide into small anastomosing branches which form the **œsophageal plexus**. At the œsophageal opening of the diaphragm the two nerves become separated from the plexus, and entering the abdomen—the left nerve in front of the œsophagus, the right nerve behind it—they terminate by supplying the stomach and other abdominal organs.

The communications and branches of the pneumogastric nerve may be described as (i.) ganglionic, (ii.) cervical, (iii.) thoracic, and (iv.) abdominal (Fig. 532).

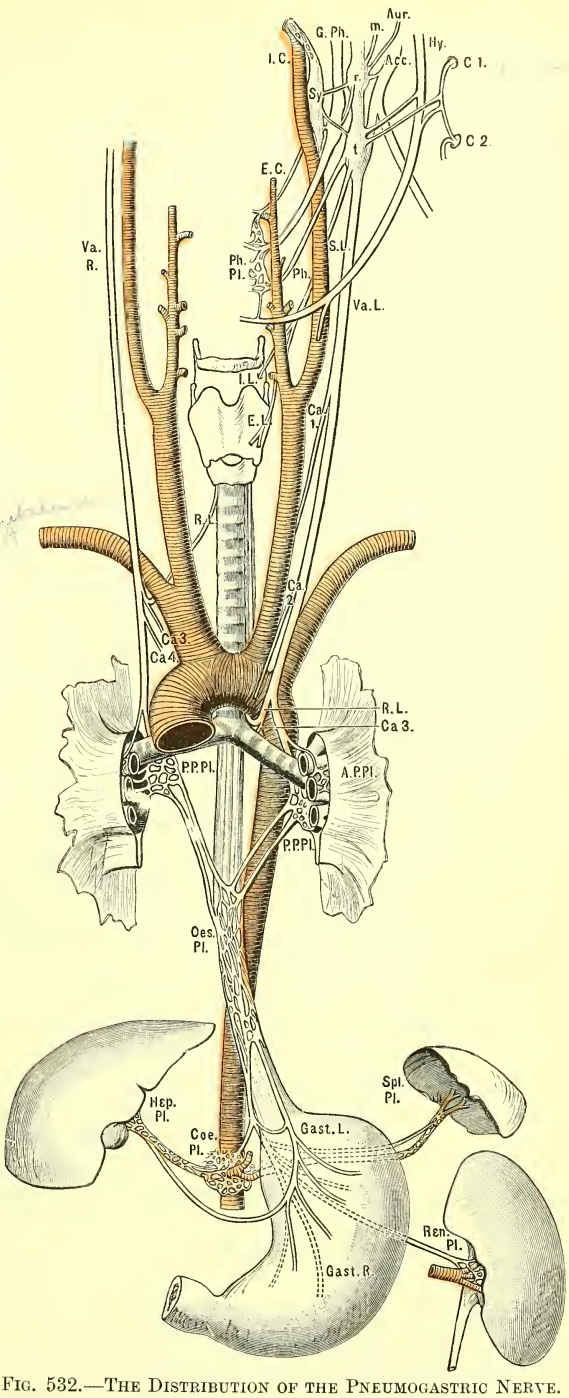


FIG. 532.—THE DISTRIBUTION OF THE PNEUMOGASTRIC NERVE.

Var.R, Va.L, Right and left vagi ; r, Ganglion of the root and connexions with Sy, Sympathetic, superior cervical ganglion ; G.Ph, Glosso-pharyngeal ; Acc, Spinal accessory nerve ; m, Meningeal branch ; Aur, Auricular branch ; t, Ganglion of the trunk and connexions with Hy, Hypoglossal nerve ; C1, C2, Loop between the first two cervical nerves ; Sy, Sympathetic ; Acc, Spinal accessory nerve ; Ph, Pharyngeal branch ; Ph.Pl, Pharyngeal plexus ; S.L, Superior laryngeal nerve ; I.L, Internal laryngeal branch ; E.L, External laryngeal branch ; I.C, Internal, and E.C, External carotid arteries ; Ca1, Superior cervical cardiac branch ; Ca2, Inferior cervical cardiac branch ; R.L, Recurrent laryngeal nerve ; Ca3, Cardiac branches from recurrent laryngeal nerves ; Ca4, Thoracic cardiac branch (right vagus) ; A.P.Pl, Anterior, and P.P.Pl, Posterior pulmonary plexuses ; Oes.Pl, Œsophageal plexus ; Gast.R, and Gast.L, Gastric branches of vagus (right and left) ; Coe.Pl, Cœliac plexus ; Hep.Pl, Hepatic plexus ; Spl.Pl, Splenic plexus ; Ren.Pl, Renal plexus.

The **ganglion of the root** (g. jugulare) is small and spherical. It occupies the jugular foramen, and gives off two branches—meningeal and auricular.

The **meningeal branch** passes backwards to supply the dura mater of the posterior fossa of the base of the skull.

The **auricular branch** (Arnold's nerve) ascends to the ear in a fissure between the jugular and stylo-mastoid foramina. It receives near its origin a twig from the tympanic branch of the glosso-pharyngeal nerve, and usually communicates with the facial nerve by a branch arising from the latter in the aqueduct of Fallopius. The nerve is distributed to the back of the pinna and the external auditory meatus, and communicates superficially with the posterior auricular nerve.

Communications.—Besides supplying the meningeal and auricular branches, the ganglion of the root of the pneumogastric nerve receives communications from (1) the superior cervical ganglion of the sympathetic; (2) the spinal accessory nerve; and (3) the petrous ganglion of the glosso-pharyngeal nerve (sometimes).

The **ganglion of the trunk** of the nerve (g. nodosum), placed immediately below the preceding, is large and fusiform. Like the previous ganglion, it supplies two branches—the pharyngeal and superior laryngeal nerves.

The **pharyngeal branch** receives its fibres (through the ganglion) from the spinal accessory nerve. It passes obliquely downwards and inwards to the pharynx between the internal and external carotid arteries, and combines with the pharyngeal nerves from the glosso-pharyngeal and superior cervical ganglion of the sympathetic to form the **pharyngeal plexus**. From this plexus the muscles of the pharynx and soft palate (except the stylo-pharyngeus and tensor palati) are supplied. The **lingual branch** is a small nerve which separates itself from the plexus and joins the hypoglossal nerve in the anterior triangle of the neck.

The **superior laryngeal nerve** (n. laryngeus superior) passes obliquely downwards and inwards, behind the external and internal carotid arteries, towards the thyroid cartilage. It divides in its course into two unequal parts—a larger internal and a smaller external laryngeal nerve.

The **internal laryngeal nerve** (ramus internus) passes inwards into the larynx between the middle and inferior constrictor muscles of the pharynx and through the thyro-hyoid membrane. It supplies the mucous membrane of the larynx, reaching upwards to the epiglottis and base of the tongue, and forms communications beneath the ala of the thyroid cartilage with the branches of the inferior laryngeal nerve.

The **external laryngeal nerve** (ramus externus) passes downwards upon the inferior constrictor muscle of the pharynx. It supplies branches to that muscle, and ends in the crico-thyroid muscle.

Communications.—Besides supplying these pharyngeal and laryngeal nerves, the ganglion of the trunk of the pneumogastric has the following communications with other nerves: (1) with the superior cervical ganglion of the sympathetic; (2) with the hypoglossal; (3) with the loop between the first and second cervical nerves; and (4) with the accessory part of the spinal accessory nerve. This part of the nerve applies itself to the ganglion, and thereby supplies to the vagus nerve the inhibitory fibres for the heart, as well as the motor fibres for the pharynx, œsophagus, stomach and intestines, larynx and respiratory organs.

Branches of the Pneumogastric in the Neck.—In the neck the pneumogastric nerve supplies cardiac branches and (on the right side) the inferior or recurrent laryngeal nerve (Fig. 532).

The **cardiac branches** are **superior** and **inferior**. *On the right side* both cardiac branches pass downwards into the thorax behind the subclavian artery, and proceed alongside the trachea to join the deep cardiac plexus. *On the left side* the two nerves separate on reaching the thorax. The *superior nerve* passes deeply alongside the trachea to join the deep cardiac plexus. The *inferior nerve* accompanies the pneumogastric nerve over the aortic arch, along with the superior cervical cardiac branch of the sympathetic, to end in the superficial cardiac plexus.

The **right inferior laryngeal nerve** arises at the root of the neck, as the pneumogastric nerve crosses over the first part of the subclavian artery. It hooks round the artery, and passes obliquely upwards and inwards behind the subclavian,

the common carotid, and the inferior thyroid artery and the thyroid body. It finally disappears beneath the lower border of the inferior constrictor muscle, and ends in supplying the muscles of the larynx. In its course it gives off the following branches :—

(1) **Cardiac branches** arise as the nerve winds round the subclavian artery, and course downwards alongside the trachea to end in the deep cardiac plexus.

(2) **Communicating branches** to the inferior cervical ganglion of the sympathetic arise from the nerve behind the subclavian artery.

(3) **Muscular branches** supply the trachea, œsophagus, and the inferior constrictor of the pharynx.

(4) **Terminal branches** supply the muscles of the larynx (except the crico-thyroid) and communicate beneath the ala of the thyroid cartilage with branches of the internal laryngeal nerve.

Branches of the Vagus in the Thorax.—In the thorax the pneumogastric nerve forms the great pulmonary and œsophageal plexuses. The right nerve, in addition, furnishes cardiac branches; and the left nerve gives off the inferior or recurrent laryngeal nerve.

The **left inferior laryngeal nerve** differs from the nerve of the right side only in its point of origin and in the early part of its course. It springs from the pneumogastric nerve as it crosses the aortic arch, and, after hooking round the arch external to the *ligamentum arteriosum*, it passes upwards in the superior mediastinum in the interval between the trachea and œsophagus to the neck. In the neck its course and relations are similar to those of the nerve of the right side. The branches of the nerve are the same as those of the right nerve. The **cardiac branches** are larger, and, arising below the aortic arch, proceed to the deep cardiac plexus.

Cardiac branches from the right pneumogastric nerve arise in the superior mediastinum, and pass downwards alongside the trachea to join the deep cardiac plexus. On the *right side* thoracic cardiac branches are thus supplied from both the trunk of the nerve and its recurrent branch; *on the left side* the cardiac branches in the thorax arise solely from the recurrent branch.

Abdominal Branches.—After the formation of the œsophageal plexus the two pneumogastric nerves resume their course, and passing along with the gullet through the diaphragm, terminate by supplying the stomach. The *right nerve* enters the abdominal cavity behind the gullet, and is distributed to the posterior surface of the stomach. It sends communicating offsets to the cœliac, splenic, and renal plexuses. The *left nerve* applies itself to the anterior surface and lesser curvature of the stomach, to which it is distributed. It sends communicating offsets along the lesser curvature of the stomach to the right pneumogastric, and between the layers of the small omentum to the hepatic plexus.

The Thoracic Plexuses.

Cardiac Plexuses.—The cardiac branches of the pneumogastric nerve (both cervical and thoracic) combine with the cervical cardiac branches of the sympathetic to form the superficial and deep cardiac plexuses.

The **superficial cardiac plexus** is placed in the hollow of the aortic arch, superficial to the pericardium. It contains a small ganglion (**ganglion of Wrisberg**), and is joined by two small nerves—(1) the cardiac branch from the superior cervical ganglion of the sympathetic, and (2) the inferior cervical cardiac branch of the pneumogastric—both of the left side—which reach it after passing over the arch of the aorta.

Branches and Communications.—From the plexus branches of communication pass (1) to the left half of the **deep cardiac plexus**, between the aortic arch and the bifurcation of the pulmonary artery; (2) to the left **anterior pulmonary plexus** along the left branch of the pulmonary artery; (3) the branches of distribution to the heart extend along the pulmonary artery to join the **anterior** or **right coronary plexus**, which supplies the substance of the heart in the course of the right coronary artery.

The **deep cardiac plexus** is much the larger. It is placed behind the arch of the aorta, on the sides of the trachea, just above its bifurcation. It consists of two lateral parts, joined together by numerous communications around the termination of the trachea. The two portions of the plexus are different in their constitution and distribution. The *right half* of the plexus is joined by both the cervical and thoracic branches of the right pneumogastric and by the branches of the right inferior laryngeal nerve, as well as by branches from the superior, middle, and inferior cervical ganglia of the sympathetic. The *left half* of the plexus is joined by the superior cervical cardiac branch of the left pneumogastric, by branches from the left inferior laryngeal nerve, and by branches from the middle and inferior cervical ganglia of the left sympathetic; it also receives a contribution from the superficial cardiac plexus.

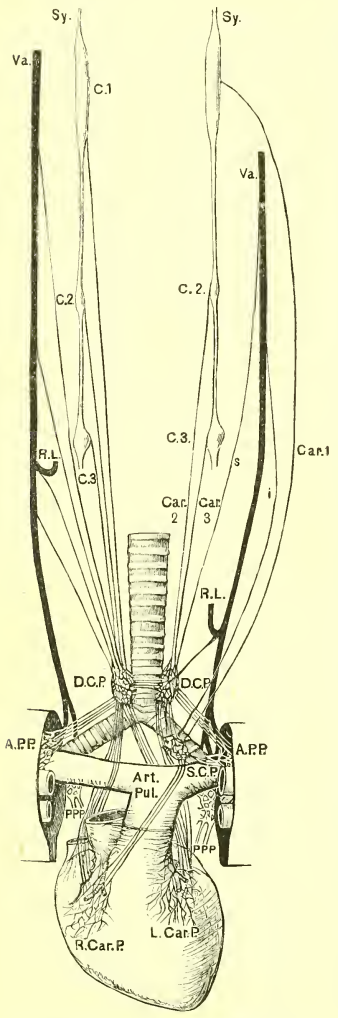


FIG. 533.—THE CONSTITUTION OF THE CARDIAC PLEXUSES.

Sy, Cervical sympathetic cord; C.1, Superior, C.2, Middle, and C.3, Inferior cervical ganglia; Car. 1, Superior, Car. 2, Middle, and Car.3, Inferior cervical cardiac sympathetic branches; Va, Pneumogastric nerve; R.L, Recurrent laryngeal nerve; s, Superior, and i, Inferior cervical cardiac branches of vagus; D.C.P, Deep cardiac plexus; S.C.P, Superficial cardiac plexus; A.P.P, Anterior pulmonary plexus; P.P.P, Posterior pulmonary plexus; R.Car.P, Right, and L.Car.P, Left coronary plexuses; Art.Pul, Pulmonary artery.

The deep cardiac plexus is distributed to the heart and lungs. The *right half* of the plexus for the most part constitutes the **anterior** or **right coronary plexus**, reaching the heart alongside the ascending aorta, and is distributed to the heart substance in the course of the right coronary artery. It is reinforced by fibres from the superficial cardiac plexus, which reach the heart along the pulmonary artery. Fibres from the right half of the deep cardiac plexus pass also to join the **posterior** or **left coronary plexus**, and others extend outwards to join the **anterior pulmonary plexus** of the right side.

The *left half* of the deep cardiac plexus, reinforced by fibres from the superficial cardiac plexus, is distributed to the heart in the form of the **left** or **posterior coronary plexus**, which is joined by a few fibres behind the pulmonary artery from the right half of the plexus, and supplies the heart substance in the course of the left coronary artery. The left half of the plexus contributes also to the **left anterior pulmonary plexus** by fibres which extend outwards to the root of the lung along the left branch of the pulmonary artery.

Pulmonary Plexuses.—As already stated, the pneumogastric nerve on each side, on reaching the back of the root of the lung, breaks up into numerous plexiform branches for the formation of the posterior pulmonary plexus. From each nerve a few fibres pass to the front of the root of the lung, above its upper border, to form the much smaller anterior pulmonary plexus.

The **anterior pulmonary plexus** on each side is joined by a few fibres from the corresponding part of the deep cardiac plexus, and on the left side from the superficial cardiac plexus as well. It surrounds and supplies the constituents of the root of the lung anteriorly.

The **posterior pulmonary plexus**, placed behind the root of the lung, is formed by the greater part of the pneumogastric nerve, reinforced by fine branches from the second, third, and fourth thoracic ganglia of the sympathetic. Numerous branches proceed from it in a plexiform manner along the bronchi and vessels into the substance of the lung.

Œsophageal Plexus (plexus gulæ). — The œsophagus in the thorax is supplied by the pneumogastric nerve both in the superior and posterior mediastinum. *In the superior mediastinum* it receives branches from the pneumogastric nerve on the right side, and from its recurrent laryngeal branch on the left side.

In the posterior mediastinum it is surrounded by the œsophageal plexus, formed from the trunks of the pneumogastric nerves emerging from the posterior pulmonary plexus, which form a large plexus surrounding the gullet. This part of the œsophagus also receives fibres from the great splanchnic nerve and ganglion. From the œsophageal plexus branches supply the muscular wall and mucous membrane of the œsophagus.

Pericardiac branches are also supplied from the plexus to the posterior surface of the pericardium.

The Eleventh or Spinal Accessory Nerve.

The spinal accessory nerve (n. accessorius) consists of two essentially separate parts, different both in origin and in distribution. One portion is **accessory to the vagus nerve**, and arises, in series with the fibres of that nerve, from the side of the medulla oblongata. The other, **spinal portion**, arises from the lateral aspect of the spinal cord, between the ventral and dorsal roots of the spinal nerves, its origin extending from the level of the accessory portion as low as the origin of the sixth cervical nerve (for the deep origin, see p. 516). Successively joining together, the rootlets form a trunk which ascends in the subdural space of the spinal cord, behind the ligamentum denticulatum, to the foramen magnum. There the

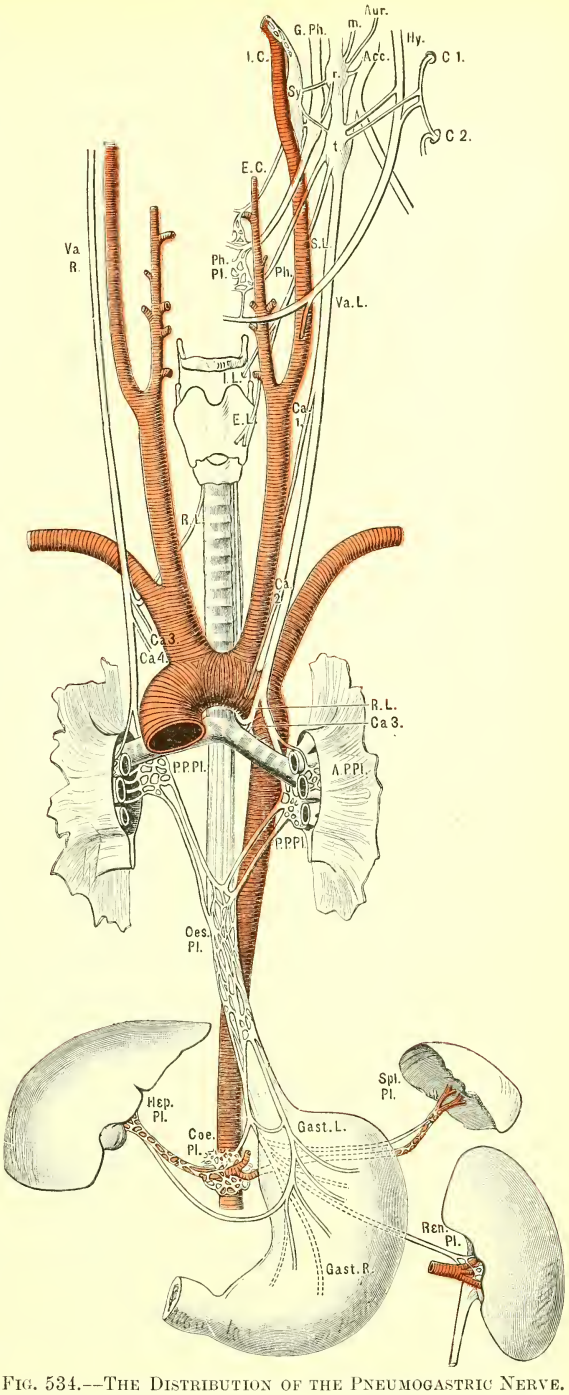


Fig. 534.—The Distribution of the Pneumogastric Nerve.

Va.R, Va.L, Right and left vagi; r, Ganglion of the root and connexions with Sy, Sympathetic, superior cervical ganglion; G.Ph, Glosso-pharyngeal; Acc, Spinal accessory nerve; m, Meningeal branch; Aur, Auricular branch; t, Ganglion of the trunk and connexions with Hy, Hypoglossal nerve; C1, C2, Loop between the first two cervical nerves; Sy, Sympathetic; Acc, Spinal accessory nerve; Ph. Pharyngeal branch; Ph.Pl, Pharyngeal plexus; S.L, Superior laryngeal nerve; I.L, Internal laryngeal branch; E.L, External laryngeal branch; I.C, Internal, and E.C, External carotid arteries; Ca1, Superior cervical cardiac branch; Ca2, Inferior cervical cardiac branch; R.L, Recurrent laryngeal nerve; Ca3, Cardiac branches from recurrent laryngeal nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.Pl, Anterior, and P.P.Pl, Posterior pulmonary plexuses; Oes.Pl, Œsophageal plexus; Gast.R, and Gast.L, Gastric branches of vagus (right and left); Cœ.Pl, Cœliac plexus; Hep.Pl, Hepatic plexus; Spl.Pl, Splenic plexus; Ren.Pl, Renal plexus.

accessory and spinal portions unite into a single trunk, which leaves the cranial cavity through the jugular foramen in the same compartment of dura mater as the pneumogastric nerve (Fig. 522, p. 678).

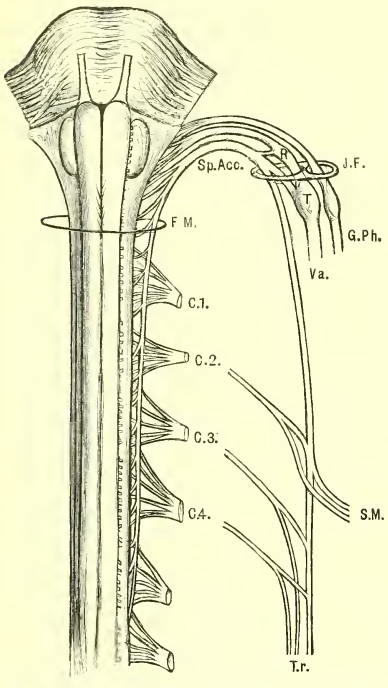


Fig. 535.—Scheme of the Origin, Connexions, and Distribution of the Spinal Accessory Nerve.

Sp.Acc, Spinal accessory nerve; C.1-4, First four cervical nerves (dorsal roots); Va, Pneumogastric nerve; R, Ganglion of the root; T, Ganglion of the trunk; G.Ph, Glosso-pharyngeal nerve; S.M, Nerves to sterno-cleido-mastoid; Tr, Nerves to trapezius; F.M, Foramen magnum; J.F, Jugular foramen.

In the jugular foramen the **accessory portion of the nerve** (after furnishing a small branch to the ganglion of the root of the pneumogastric nerve) applies itself to the ganglion of the trunk, and in part joins the ganglion, in part the trunk of the nerve beyond the ganglion. By means of these connexions the pneumogastric receives viscero-motor and cardio-inhibitory fibres.

The **spinal portion** of the nerve extends into the neck, where at first it lies along with other nerves, in the interval between the internal carotid artery and the internal jugular vein. Passing obliquely downwards and outwards over the vein, it descends beneath the sterno-mastoid muscle, which it supplies as it pierces it on its deep surface. After crossing the posterior triangle the nerve ends by supplying the trapezius muscle on its under surface. The spinal portion of the nerve *communicates* in three situations with nerves from the cervical plexus—(1) in or beneath the sterno-mastoid, with the branch for the muscle derived from the second cervical nerve; (2) in the posterior triangle, with branches from the third and fourth cervical nerves;. (3) beneath the trapezius, with the branches for the muscle derived from the third and fourth cervical nerves.

The Twelfth or Hypoglossal Nerve.

The hypoglossal nerve (n. hypoglossus) arises by numerous radicles from the front of the medulla oblongata between the pyramid and the olive (Fig. 517, p. 675) (for deep origin, see p. 515). The root fibres arrange themselves in two bundles which separately pierce the dura mater, and unite in the anterior condyloid foramen, or after emerging from the skull. In the neck the nerve arches downwards and forwards towards the hyoid bone, and then turns inwards among the suprahyoid muscles to the tongue. At first it is placed deeply, along with other cranial nerves, on the outer side of the internal carotid artery; it then curves forwards and downwards over the two carotid arteries lying beneath the digastric and stylohyoid muscles. As it crosses the external carotid artery it hooks round the occipital artery. Above the great cornu of the hyoid bone the nerve conceals the lingual artery; and it then disappears between the mylo-hyoid and hyo-glossus muscles to reach the tongue, in the muscular substance of which it terminates.

Communications.—In its course the hypoglossal nerve has the following communications with other nerves:—Near the base of the skull it is connected by small branches with (1) the superior cervical ganglion of the sympathetic; (2) the ganglion of the trunk of the pneumogastric; (3) by a larger branch, with the loop between the first two cervical nerves; (4) as it crosses the external carotid artery it receives a communication from the pharyngeal plexus (*lingual branch of the vagus*); and (5) beneath the mylo-hyoid muscle, at the anterior border of the hyo-glossus, it forms loops of communication with the lingual branch of the inferior maxillary nerve.

The **branches** of the nerve are:—(1) Recurrent; (2) Descending; (3) Thyro-hyoid; and (4) Lingual.

The **recurrent branch** passes from the nerve near its origin to supply the dura mater of the posterior fossa of the base of the skull. It probably derives its fibres from the communication with the first and second cervical nerves.

The **descending hypoglossal nerve** (n. descendens) is the chief branch given off in the neck. It arises from the hypoglossal nerve as it crosses the internal carotid artery, and descends in the anterior triangle in front of the carotid sheath. It is joined about the middle of the neck by the **descending cervical nerve** (from the second and third cervical nerves). By their union the **hypoglossal loop** (ansa

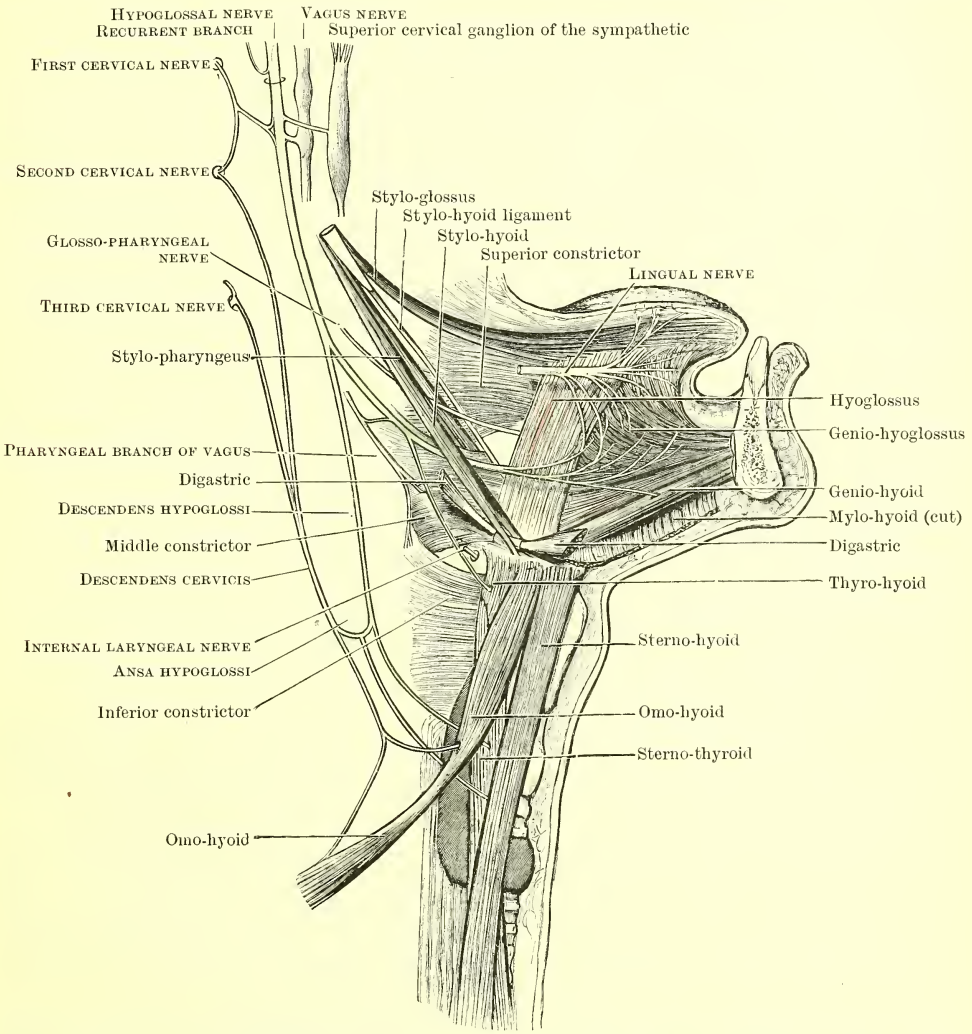


Fig. 536.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue with their Nerves.

hypoglossi) is formed, from which branches are distributed to the majority of the infra-hyoid muscles—both bellies of the omo-hyoid, the sterno-hyoid, and the sterno-thyroid. The descending hypoglossal nerve derives its fibres from the communication to the hypoglossal nerve from the loop between the first and second cervical nerves; so that the ansa hypoglossi is made up of fibres of the first three cervical nerves.

The **nerve to the thyro-hyoid muscle** is a small branch which arises from the hypoglossal nerve before it passes beneath the mylo-hyoid muscle. It descends behind the great cornu of the hyoid bone to reach the muscle. When traced backwards this nerve is found associated with the loop between the first and second cervical nerves.

The **lingual branches** of the hypoglossal nerve are distributed to the hyo-glossus, genio-hyoid, and genio-hyo-glossus, and to all the intrinsic muscles of the tongue. The nerve to the genio-hyoid is said to be derived from the loop between the first and second cervical nerves. It is not known if these two nerves are implicated in the innervation of the proper muscles of the tongue, but it appears certain that the muscles named—the genio-hyoid, thyro-hyoid, sterno-hyoid, omo-hyoid, and sterno-thyroid—are not supplied by the hypoglossal, but only by cervical nerves, the genio-hyoid by the first two, the other muscles by the first three cervical nerves.

THE DEVELOPMENT OF THE CRANIAL NERVES.

Omitting the first and second nerves, there is an obvious likeness in the development of the several cranial nerves to the formation of the dorsal, afferent or sensory, and the ventral, efferent or motor, roots of the spinal nerves. The **afferent roots** of the cranial nerves arise from collections of cells which bud off from the alar lamina of the brain, homologous with the dorso-lateral part of the spinal cord. These cells give rise to central and peripheral processes, like the similar processes from the dorsal ganglia of the spinal nerves, producing on the one hand the root fibres connected with the brain, and on the other hand the fibres of the nerve proceeding to the periphery. The **efferent roots**, like the ventral roots of the spinal nerves, arise as the peripheral processes of neuroblasts located in the basal lamina of the primitive brain, which is homologous with the ventro-lateral portion of the spinal cord. The different efferent nerves may be separated into two series, according as they arise from the mesial or lateral parts of the basal lamina. The third, fourth, sixth, and twelfth nerves arise from the mesial part of the lamina; the efferent fibres of the fifth, seventh, ninth, tenth, and eleventh nerves arise from the lateral part of the lamina.

The **olfactory nerves** are associated in their development with the formation of the nasal pit and the olfactory bulb.

The **nasal pits** appear in each side of the front of the head at a little later period than the formation of the lens and the auditory vesicle. They become converted into the nasal cavities by the formation of the pre-oral visceral clefts and arches,—fronto-nasal and ethmo-vomerine in the middle line, and lateral ethmoid and maxillary processes at the sides (p. 38).

The **Rhinencephalon** or **olfactory bulb** is a hollow outgrowth from each telencephalon or cerebral hemisphere, which appears in the first month. It grows forwards into relation with the deep surface of the nasal pit. In many animals (as in the horse) the olfactory bulb remains hollow; but in the human subject it loses its lumen and becomes a solid bulb (**olfactory bulb**) connected to the brain by a narrow stalk, the **olfactory tract.**

The **epithelium of the nasal pit** is responsible for the formation of the olfactory nerves. There are two views as to the mode of their development from the epithelial cells. Both views admit the proliferation of the epithelium of the nasal pit so as to produce *neuroblasts.* According to the one view these neuroblasts detach themselves from the epithelial surface, and constitute **an olfactory ganglion** which becomes applied to and incorporated with the olfactory bulb. The cells of the ganglion become bi-polar, and the peripheral axons constitute the *olfactory nerves*, while the central axons (in the second month) proceed backwards to the brain along the olfactory tract. According to the other view (based on Disse's investigations), the proliferating cells of the nasal epithelium remain in the wall of the nasal pit, and become the *olfactory cells* of the nasal cavity, with peripheral processes projecting to the surface of the epithelium. Their central axons become the olfactory nerve fibres which end in the olfactory bulb, forming dendrites associated with the dendritic processes of the nerve-cells of the bulb. The central axons of these latter cells develop into the fibres of the olfactory tract.

The **optic nerve** is developed wholly from the brain. Its formation begins with the outgrowth of the optic vesicle, a paired hollow outgrowth from the ventral surface of the thalamencephalon. The epiblastic invagination of the lens, growing inwards from the surface of the head, causes the collapse of the vesicle and its conversion into the **optic cup**, the narrow tube connecting the vesicle to the brain becoming the **optic stalk.** This stalk becomes solid, and forms the basis of the optic tract, optic commissure, and optic nerve. The optic cup, bilaminar in form, and by its edge clasping the lens, is embedded in mesoblastic tissue, which gives rise to the envelopes of the eyeball, etc. The *outer*

layer of the optic cup produces the layer of hexagonal pigment cells of the retina. The cells of the *inner layer* produce the tissue of the retina proper. They form neuroblasts with peripheral and central processes. The peripheral processes are converted into retinal nerve tissues; the central processes extend backwards along the optic stalk, and give rise to the fibrous structure of the optic nerve, optic commissure, and optic tract. Spongioblasts in the inner lamina of the optic cup produce the sustentacular tissue of the retina (Müller's fibres). The mesoblastic tissue surrounding the optic cup and lens gives rise to the rest of the structure of the eyeball, the formation of which is described in the section which deals with the organs of sense.

The **oculo-motor nerve** arises, like the ventral root of a spinal nerve, from a group of neuroblasts in the mesial part of the basal lamina of the mid-brain. The peripheral fibres extend forwards, to end around the optic cup in the mesoblastic tissue, from which the eye muscles are derived. Numerous cells are carried along with the cell processes in their course, and these have been described as being concerned in the formation of the ciliary ganglion.

The **trochlear nerve** also arises from a group of neuroblasts occupying the mesial part of the basal lamina of the mid-brain, close to its junction with the hind-brain. The peripheral processes do not emerge directly from the brain, but extend dorsally from their origin along the side of the brain to its dorsal aspect, where they appear, after decussating with the fibres of the opposite nerve, just behind the quadrigeminal lamina.

The **trigeminal nerve** is developed by means of a large dorsal and a small ventral root. Their origin to a large extent resembles the mode of formation of the roots of a spinal nerve.

The large **dorsal (afferent) root** is formed by means of a cellular bud from the alar lamina of the hind-brain. This bud separates from the brain, and forms the Gasserian ganglion. Its cells becoming bipolar, like the cells of a spinal ganglion, are secondarily connected with the brain by means of their central processes; while the peripheral processes, separating into three groups, proceed along the fronto-nasal and maxillary processes, and along the mandibular arch, to form the three main divisions of the nerve. Numerous cells accompany each main division in its course from the ganglion, and form eventually the subordinate ganglia—the *ciliary* on the ophthalmic nerve, the *spheno-palatine* on the superior maxillary nerve, and the *otic ganglion* on the inferior maxillary nerve.

The small **ventral (efferent) root** of the trigeminal nerve, like the motor ventral root of a spinal nerve, is later in its appearance than the sensory root. It arises as the peripheral fibres of a group of neuroblasts occupying the lateral part of the basal lamina of the hind-brain, which proceed directly to the surface to join the inferior maxillary division of the nerve.

The **abducent nerve** resembles in its mode of development the oculo-motor and trochlear nerves with which in its origin it is in series. It is formed by the peripheral processes of a group of neuroblasts in the mesial part of the basal lamina in the upper part of the hind-brain. These processes pierce the part of the brain in which, at a later stage, the fibres of the pyramid are developed. They then proceed to the mesoblastic tissue round the optic cup, which is destined to form the eye muscles.

The **facial nerve** has developmentally a double origin. (1) In connexion with the formation of the auditory nerve a group of cells becomes separated from the alar lamina of the hind-brain opposite the auditory vesicle. This group becomes separated into three parts, of which the middle portion is the rudiment of the **geniculate ganglion** (or afferent root). (2) The **efferent root** of the nerve arises from a group of neuroblasts in the lateral part of the basal lamina of the hind-brain, in series with efferent fibres of the vago-glosso-pharyngeal nerves; after a tortuous course within the brain its fibres emerge beneath the above-mentioned cellular mass, opposite the auditory vesicle. They are joined by the ganglionic root, and in their course round the auditory vesicle become embedded in the auditory capsule (aqueduct of Fallopius). The chorda tympani nerve appears early as a branch of the facial nerve. It is probable that the pars intermedia, the geniculate ganglion, and the chorda tympani nerve together represent the **dorsal afferent element** in the constitution of this nerve.

The **auditory nerve** arises as a cellular bud from the alar lamina of the hind-brain, dorsal to the efferent portion of the facial nerve and opposite to the auditory vesicle, and in close association with the latter.

Becoming separated from the brain, the cellular mass separates into three portions, of which the middle part is associated with the facial nerve and pars intermedia (as the geniculate ganglion), while the mesial and lateral parts are converted into the mesial (vestibular) and lateral (cochlear) ganglia and roots of the auditory nerve. The cells

becoming bipolar, their central processes are secondarily connected with the brain on the dorsal (lateral) aspect of the facial nerve; the peripheral processes proceed to the auditory vesicle, to which they are distributed as the vestibular and cochlear nerves. Numerous cells are carried along with the nerve trunks into relation with the auditory capsule, and constitute the vestibular and cochlear ganglia.

The **glosso-pharyngeal** and **pneumogastric nerves** are developed from the side of the hind-brain, both in the same way, and each by two roots. A collection of cells separates itself from the alar lamina of the hind-brain behind the auditory vesicle to form the **ganglionic afferent root.** The ganglion of the pneumogastric is much larger than that of the glosso-pharyngeal. Each ganglion becomes divided into two parts, a proximal and a distal portion, connected together by a commissural band of fibres. The proximal ganglion (jugular ganglion of the glosso-pharyngeal; ganglion of the root of the pneumogastric) is secondarily connected by centripetal fibres to the hind-brain. From the distal ganglion (petrous ganglion of the glosso-pharyngeal; ganglion of the trunk of the pneumogastric) peripheral fibres grow outwards to form the nerve trunk.

Each nerve is also provided with a small **efferent root**, consisting of nerve fibres, arising from a collection of neuroblasts in the lateral part of the basal lamina of the hind-

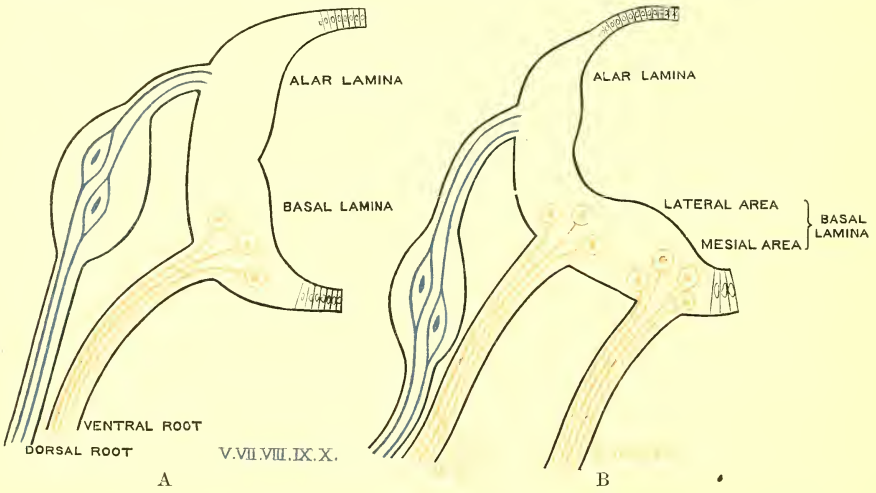


FIG. 537.—COMPARISON OF ORIGINS OF NERVE ROOTS FROM SPINAL CORD AND HIND-BRAIN (after His).
A. Spinal cord; B. Hind-brain.

brain, and emerging beneath the ganglionic root at the junction of the alar and basal laminæ (in series with the fibres of the efferent root of the facial nerve above and of the spinal accessory nerve below).

The **spinal accessory nerve** arises in two parts—one medullary, the other spinal. The **medullary** (accessory) portion develops as the processes of a series of neuroblasts in the lateral portion of the basal lamina of the hind-brain, which emerge in series with the efferent roots of the glosso-pharyngeal and pneumogastric nerves. The **spinal portion** arises as the processes of a group of neuroblasts in the ventral part of the medullary tube (anterior cornu), which, turning outwards, emerge as a series of roots on the lateral aspect of the spinal cord.

The **hypoglossal nerve** is developed, not in series with the nerves above mentioned, but like the third, fourth, and sixth nerves, from the mesial part of the basal lamina of the hind-brain, in the space between the glosso-pharyngeal and other nerves above, and the first cervical nerve below. It is formed as a series of peripheral processes from a collection of neuroblasts occupying the hind-brain. **Froriep's ganglion** is a transitory collection of nerve cells developed from the alar lamina of the hind-brain on the dorsal aspect of the nerve, and represents in a rudimentary condition its dorsal ganglionic root. It gives off no branches and soon disappears.

THE MORPHOLOGY OF THE CRANIAL NERVES.

The head and face, possibly the oldest, and from every point of view the most fundamental and important portion of the bodily fabric, present in some respects a more conservative type of structure, and in other aspects have been subject to more profound alterations than other parts

of the body. Segmentation is characteristic of the trunk, pervading bones, muscles, vessels, and nerves. An absence of true segmentation is characteristic of the head region—omitting for the moment the cranial nerves. The head is characterised by the possession of an unsegmented tubular nervous system, enclosed in a bony capsule not obviously segmental, with which the capsules of the sense-organs become united. The pre-oral and post-oral visceral arches and clefts are not truly segmental like the costal arches of the trunk. The branchial clefts are said to be inter-segmental; and their muscles (associated with the myoblast surrounding the developing heart) are described as visceral, and not myotomic, so that the branchial vessels and nerves (similarly) are not to be regarded as comparable to the segmental vessels and nerves of the trunk. The truly segmental structures present are certain persistent myotomes or muscle plates, which give rise to muscles innervated by the third, fourth, sixth, and twelfth cranial nerves.

Another difficulty in the morphology of the head arises in the absence of body cavity, and the consequent difficulty of differentiating the somatic and splanchnic mesoblast, and the somatic and splanchnic distribution of a given nerve.

Under these circumstances there is little help to be derived from head structures other than the nerves themselves in seeking a solution of the question of the morphological relations of the cranial nerves. The spinal nerves are, generally speaking, all alike. The cranial nerves, on the other hand, are all different. Scarcely any two nerves are alike; and no single cranial nerve possesses in itself all the characteristic features of a spinal nerve. As seen in relation to their development, the cranial nervous system possesses a series of dorsal ganglia, comparable in position and development to the spinal ganglia from which afferent nerves arise; and the efferent roots are developed in the same way, and occupy somewhat the same position as the ventral roots of the spinal nerves. But there is no single complete segmental nerve in the head. The very essence of the architecture of the head is a want of segmentation; and this character is shared by the cranial nerves. In addition it must be borne in mind that, in relation to the mammalian head, there are organs which have no homologues in the trunk, and on whose existence the arrangement of the cranial nerves depends—*e.g.* sense-organs and gill-arches.

Among the cranial nerves there are several which possess a resemblance to one or other of the elements of a typical spinal nerve. In the neck the origin of the fibres of the spinal accessory nerve is from the side of the spinal cord, and it is in series with the motor roots of the vago-glosso-pharyngeal, facial, and fifth nerves. His (as shown in the account of the development of the nerves) has described the neuroblastic origin of the motor roots of these nerves from the lateral part of the basal lamina of the primitive brain. They thus form a series apart—lateral motor roots—separable from the series of motor roots originating from the mesial part of the basal lamina, comprising those of the third, fourth, sixth, and twelfth nerves; the latter nerve roots being comparable to and in series with the ventral roots of the spinal nerves. The lateral motor roots are not represented in the spinal series except in the neck. It is questionable if there is any fundamental distinction between the lateral and ventral motor roots of the cranial nerves. The spinal accessory fibres, for example, when traced into the spinal cord, have an origin from the anterior cornu of the cord, and only differ from the motor or ventral root fibres of a spinal nerve in their different course to the surface. The ganglia in association with the cranial nerves are comparable to the spinal ganglia. The fifth nerve, with the Gasserian ganglion, the ganglion of the facial, the ganglia of the auditory, of the glosso-pharyngeal and the vagus, and the transitory (Froriep's) ganglion of the hypoglossal nerves, arise from the brain in a comparable position, and in the same way as the spinal ganglia. But another series of structures —the sense organs of the lateral line, and the so-called "epibranchial" organs which are highly developed in lower vertebrates (*e.g.* elasmobranchs), and which appear transitorily only, or are absent altogether in mammalian development, may possibly have a share in the formation of certain of these ganglia or parts of them (*e.g.* ciliary ganglion, geniculate ganglion, ganglia of the auditory nerve, petrosal ganglion of the glosso-pharyngeal, and the ganglion of the trunk of the vagus).

Certain of the cranial nerves are apparently distinctly **segmental**, supplying muscles derived from the persisting myotomes of the head. The **first three myotomes** are said to give rise to the muscles of the eyeball. The *first* produces the superior rectus, inferior rectus, internal rectus, and inferior oblique muscles, and its segmental nerve is the **oculo-motor.** The *second myotome* is said to produce the superior oblique muscle, and its segmental nerve is the **trochlear.** The *third myotome* is said to produce the external rectus muscle, and its segmental nerve is the **abducent.** It has been asserted that the tongue muscles are derived from the **last three or four cephalic and first cervical myotomes**, and that the **hypoglossal nerve** is the segmental nerve for these myotomes, comprising the motor elements of several (four or five) segmental nerves. The intervening myotomes between the first three and this occipital series disappearing, the corresponding elements of segmental nerves are supposed to be absent also (Fig. 538).

Certain of the cranial nerves are essentially related to the structures derived from and associated with the pre-oral and post-oral **visceral clefts and arches** (Fig. 539). The **trigeminal nerve** is essentially the nerve of the **mandibular arch.** By its efferent root it supplies the muscles of that arch. By its afferent root and branches it is related to (1) the fronto-nasal process (ophthalmic division and ciliary ganglion); (2) the maxillary arch (superior maxillary nerve); and (3) the mandibular arch (inferior maxillary nerve). The mandibular is at first the main nerve; and the maxillary division is sometimes regarded as a subordinate branch (præ-branchial, præ-trematic) for the supply of the anterior margin of the cleft (mouth), with which the nerve is in relation. The ophthalmic nerve is sometimes regarded as a morphologically separate nerve. The nerves to these arches have been compared to the anterior primary divisions of spinal

nerves, the branches which they supply to the forehead and temple (frontal, orbital, and auriculo-temporal) representing the posterior primary divisions. The ganglia on each division of the nerve are formed as extensions from the Gasserian ganglion.

The **facial nerve** is essentially the nerve of the **second (hyoid) arch**, and the cleft in front of that arch (spiracular cleft, Eustachian tube). Its motor root supplies the muscles of that arch (stapedius, stylo-hyoid, and digastric), and the epicranial and facial muscles and platysma myoides, which are developments from the hyoid arch (Rabl). The **chorda tympani nerve** is regarded as the subordinate (præ-branchial, præ-trematic) branch to supply the anterior margin of the first post-oral cleft. It is possible that the geniculate ganglion, with the pars intermedia and the chorda tympani, may, in part at least, represent the ganglionic and afferent element of the nerve. Or the geniculate ganglion, and the nerves in relation to it, may be associated with an "epibranchial" sense-organ.

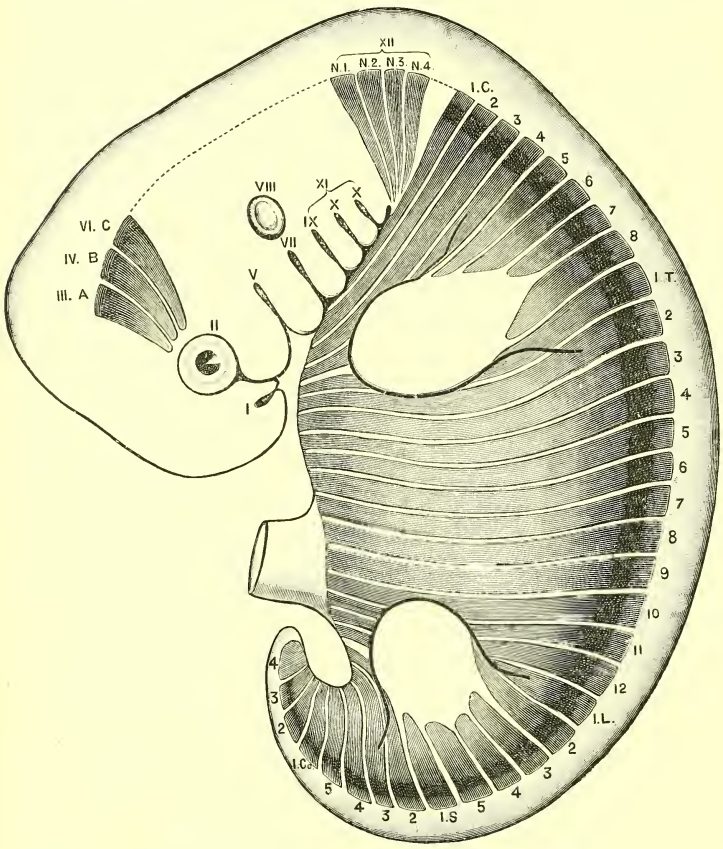


FIG. 538.—SCHEME TO ILLUSTRATE THE DISPOSITION OF THE MYOTOMES IN THE EMBRYO IN RELATION TO THE HEAD, TRUNK, AND LIMBS.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, 4, Last persisting cephalic myotomes; C, T, L, S, Co, The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cranial nerves, and the structures with which they may be embryologically associated.

The **auditory nerve**, on the other hand, may be either the sensory element of the branchial nerve, associated with the **hyoid arch** and first post-oral cleft, or it may represent the nerve or nerves belonging to ancestral sense-organs of the lateral line.

The **glosso-pharyngeal** is the branchial nerve of the **third post-oral** (*thyro-hyoid*) **arch** and the cleft in front. Its efferent fibres supply the muscle of this arch,—the stylo-pharyngeus. The superior constrictor of the pharynx is also assigned to this arch; the middle and inferior muscles to the fourth (first branchial) arch. The afferent portion of the nerve is possibly composed of two separate parts; the petrous ganglion being associated with an epibranchial or lateral line sense-organ, and the rest of the nerve forming the afferent fibres for the gill-cleft and arch. The lingual branches are regarded as the main stem (post-trematic), the pharyngeal branches as subordinate branches; the tympanic branch being the præ-branchial or præ-trematic branch for the anterior margin of the third gill-cleft.

The **pneumogastric nerve** is generally regarded as representing the fusion of all the branchial nerves behind the glosso-pharyngeal. Its efferent fibres are in series with those of the glosso-pharyngeal above and the spinal accessory nerve below, and belong to the lateral series of His. Its afferent fibres, like those of the glosso-pharyngeal, represent two elements. The lower ganglion has possible connexions with epibranchial sense-organs—the rest of the nerve representing the fused branchial branches of fishes. The **superior laryngeal nerve** is looked upon as the branchial nerve of the **fourth**, and the **inferior laryngeal nerve** as the branchial nerve of the **fifth arch**. While the relation of the nerve to the hinder gill-arches and clefts makes it possible to understand the innervation by the vagus of the heart and lungs, no satisfactory explanation is forthcoming of the passage of the nerve into the abdomen, and its distribution to the stomach and other organs below the diaphragm.

The **spinal accessory nerve** consists of two parts. The *accessory portion* of the nerve consists of efferent fibres for the **branchial region**, in series with the lateral motor roots of the glosso-pharyngeal and vagus nerves. The *spinal portion* of the nerve is also composed of efferent fibres, and represents the only lateral motor elements arising from the spinal cord.

Olfactory Nerve.—There is absolute uncertainty regarding the morphology of this nerve. It consists of three elements: (1) the **olfactory bulb**, derived from the cerebral hemisphere, solid in man, but a hollow cerebral diverticulum in certain animals, and forming the rhinencephalon; (2) the **olfactory ganglion**, with its central and peripheral processes, derived from the ectoderm; (3) the **nasal pit.** Attention has been specially fixed on the olfactory ganglion, which has been compared to (1) a dorsal spinal ganglion, derived from the anterior end of the medullary groove; and to (2) a lateral line sense-organ.

The **optic nerve** also presents an insoluble problem in regard to its morphological position in the series of cranial nerves. The optic stalk and optic cup have been regarded as a highly-modified dorsal ganglion; but there is insuperable difficulty in accepting this view. The peripheral processes do not become connected with either ectodermal or mesoblastic structures, but become the tissue of the retina; while the central processes, growing backwards, envelop the optic stalk, and obtain connexions with the brain. The retina must be regarded as a highly-modified layer, morphologically in series with the wall of the fore-brain; and the ectodermal structure of superficial origin comparable to the olfactory ganglion or the auditory vesicle is the lens (which may possibly be homologous with a lateral line sense-organ). The optic nerve, optic commissure, and optic tract are then to be looked upon as cerebral commissures, and not as nerves in the ordinary sense.

The simplest and most primitive condition of the head, in relation to the morphology of the cranial nerves, is found before the formation of the gill-clefts, when the salient features are a tubular and simple brain, and a series of superficial invaginations which pass from the surface inwards to become connected with outgrowths corresponding to them from the primitive brain. On either side of the head three hollow invaginations occur:—(1) The **nasal pit** bearing the olfactory epithelium becomes connected by the olfactory ganglion with the rhinencephalon, an outgrowth from the fore-brain, and so forms the basis of an olfactory organ and nerve; (2) a similar invagination produces the **lens**, connected with a protrusion of the optic vesicle from the fore-brain, by which the basis of the eye and the optic nerve is formed; (3) behind the buccal cavity a third invagination forms the **auditory vesicle**, which is connected with the solid extension from the hind-brain of the acoustic ganglia, to form the essentials of the organ of hearing and auditory nerve.

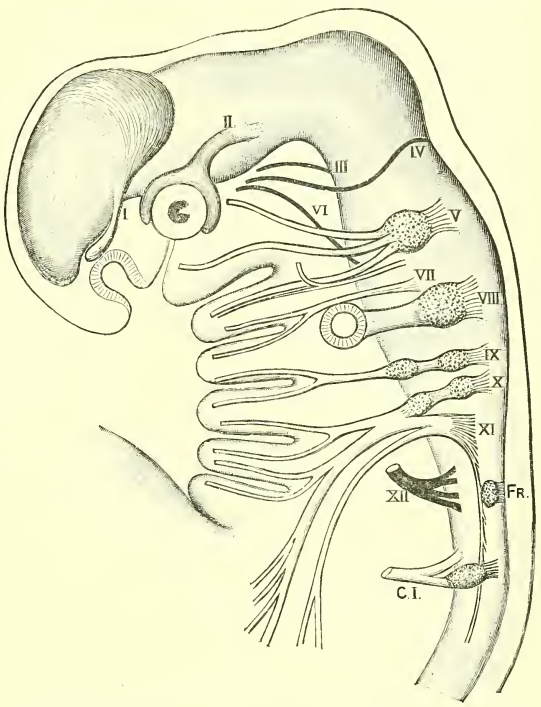


Fig. 539.—Scheme to illustrate the Embryological Arrangement of the Cranial Nerves.

I. to XII. Cranial Nerves; Fr, Froriep's ganglion; CI., Roots and trunk of the first cervical nerve.

The trigeminal nerve is essentially the nerve of the buccal cavity and the subordinate cavities, nasal and oral, derived from it. The **branchial arches and clefts** are secondary structures, and their nerves are (1) the trigeminal for the first (mandibular) arch and the cleft in front of it; (2) the facial for the second (hyoid) arch and cleft; (3) the glosso-pharyngeal for the third (thyro-hyoid) arch and cleft; and (4) the pneumogastric for the succeeding arches and clefts. The bulbar part of the spinal accessory nerve is inseparable from the motor portion of the vago-glosso-pharyngeal nerves; the spinal part is beyond the series of the cranial nerves.

Lastly, there are certain truly **segmental nerve elements**, motor fibres which, remaining associated with certain persistent cephalic myotomes, give rise to the oculo-motor, trochlear, abducent, and hypoglossal nerves.

THE SYMPATHETIC NERVOUS SYSTEM.

The sympathetic nervous system consists of a pair of elongated gangliated cords (nervi sympathici), extending from the base of the skull to the coccyx; connected, on the one hand, by a series of branches to the spinal nervous system, and on the other hand giving off an irregular series of branches to the viscera. At its cephalic end each sympathetic cord is continued in a plexiform manner into the cranial cavity along with the internal carotid artery, and forms complex relation-

ships with certain cranial nerves. At their caudal ends the two sympathetic cords become joined together by fine filaments, and are connected by the coccygeal ganglion (g. impar).

The sympathetic system (1) serves to rearrange and distribute fibres derived from the cerebro-spinal system to the viscera and vessels of the splanchnic area; (2) it transmits to the cerebro-spinal system afferent fibres from the viscera; and (3) it transmits fibres to the vessels, involuntary muscles, and glands, in the course of the somatic divisions of the spinal nerves.

General Structure of the Sympathetic System.—The sympathetic system is composed of two elements—ganglia and nerve fibres.

The **ganglia** (g. trunci sympathici) are variable in number, form, size, and position. They are not definitely segmental in position, but they are always connected together by a system of narrow commissural cords of nerve fibres. A ganglion consists of a larger or smaller number of multipolar nerve cells, enclosed in a capsule of connective tissue. Each cell is provided with one *axon* and a number of *dendrites*. The axon may enter into the composition of (*a*) the commissural cord; (*b*) a central branch (gray ramus communicans); or (*c*) a peripheral branch from the sympathetic cord. These axons are commonly medullated at their origin, but become non-medullated in their course from the parent cell. Besides these ganglia, two other series of ganglia are present in connexion with the peripheral branches of the sympathetic: intermediate or **collateral ganglia**, on the branches or in the sympathetic plexuses; and **terminal ganglia**, in close relation to the endings of the nerves in the viscera.

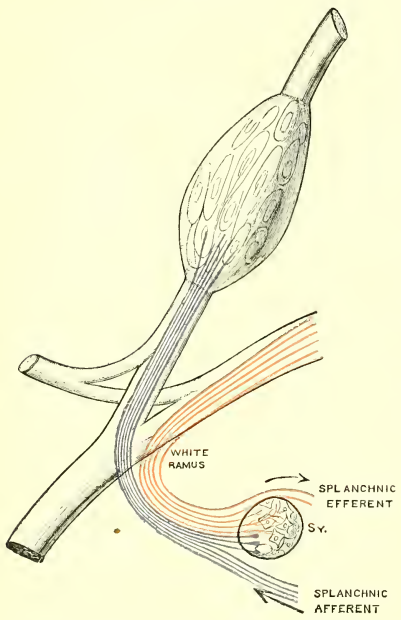


Fig. 540.– Scheme of the Constitution of the White Ramus Communicans of the Sympathetic.

The roots and trunks of a spinal nerve are shown, with the white ramus passing between the spinal nerve and a sympathetic ganglion (Sy). The splanchnic efferent fibres (in red) are shown, partly ending in the ganglion, and partly passing beyond the ganglion into a peripheral branch. The splanchnic afferent fibres (in blue) are shown, partly entering the ganglion, and passing upwards or downwards in the gangliated cord; partly passing over the cord into peripheral branches.

The **nerve fibres** in the sympathetic system are of two classes, medullated and non-medullated. The distinction is not absolute. The medullated fibres may lose their medullary sheaths before reaching their terminations; and the non-medullated fibres may at their origin possess a medullary sheath. The **medullated fibres** form the series of *white rami communicantes* (the visceral branches of the spinal nerves). They take origin from the anterior primary divisions of certain spinal nerves in two streams; **thoracico-lumbar** from the first or second thoracic to the second or third lumbar nerve, and **pelvic**, or **sacral**, from the second and third, or third and fourth sacral nerves. The roots of these nerves arise from both dorsal and ventral roots of the spinal nerves, but in largest numbers from the ventral root. The *fibres from the ventral root* are of very small size. They are the axons of nerve cells within the spinal cord, which enter the sympathetic cord through the white ramus, and end by forming arborisations around the cells of a sympathetic ganglion. There are three known courses for such a fibre to take in relation to the sympathetic system—(*a*) It may end in the ganglion with which it is immediately related; (*b*) it may course upwards or downwards in the commissural cord to reach a neighbouring ganglion; (*c*) it may pass beyond the gangliated cord to end in relation to cells of the peripheral (collateral) ganglia along with fibres of distribution from the sympathetic ganglia. These fibres are *splanchnic efferent fibres*; motor for the unstriped muscular tissue of the vessels and viscera, and secretory for the glands in the splanchnic area. The *fibres from the dorsal root* of the spinal nerve entering into the composition of the white ramus communicans are the axons of spinal

ganglion cells. They constitute the *splanchnic afferent fibres*, and probably traverse the sympathetic gangliated cord, passing upwards, downwards, and outwards, without being connected with its cells. They are the sensory fibres for the viscera, which they reach along with the peripheral branches arising from the sympathetic cord itself. It is not certain that fibres from the dorsal ganglia are only found in connexion with nerves provided with distinct white rami. Similar medullated fibres are found also in the gray rami communicantes.

The **non-medullated fibres** in the sympathetic system are derived from the axons of the sympathetic ganglion cells. They have different destinations. (*a*) Some fibres appear to contribute to the *formation of the commissural cord* connecting the ganglia together, and to end in arborisations round the cells of a neighbouring ganglion. (*b*) Non-medullated fibres form a large part of the system of *peripheral (splanchnic efferent) branches*, streaming into the splanchnic area in an irregular manner, both from the ganglia and the connecting commissures. (*c*) The *gray rami communicantes* form a series of non-medullated fibres (with a small number of medullated fibres intermingled) proceeding *centrally from the ganglia to the spinal nerves*. These gray rami are found in connexion with each and all of the spinal nerves. Their origin from the gangliated cord is irregular: they may come from the ganglia or the commissure; they may divide after their origin, so that two spinal nerves are supplied from one ganglion; or two ganglia may supply branches to a single spinal nerve. The gray ramus is distributed along the somatic divisions of the spinal nerves, supplying branches to unstriped muscular fibres (vaso-motor, pilo-motor) and glands (secretory). They also provide small recurrent branches, ending in the membranes enveloping the spinal nerve-roots. Mingled with the non-medullated fibres of the gray rami are found a small number of medullated fibres, regarded as medullated sympathetic fibres, and axons from the dorsal spinal ganglia incorporated with this ramus.

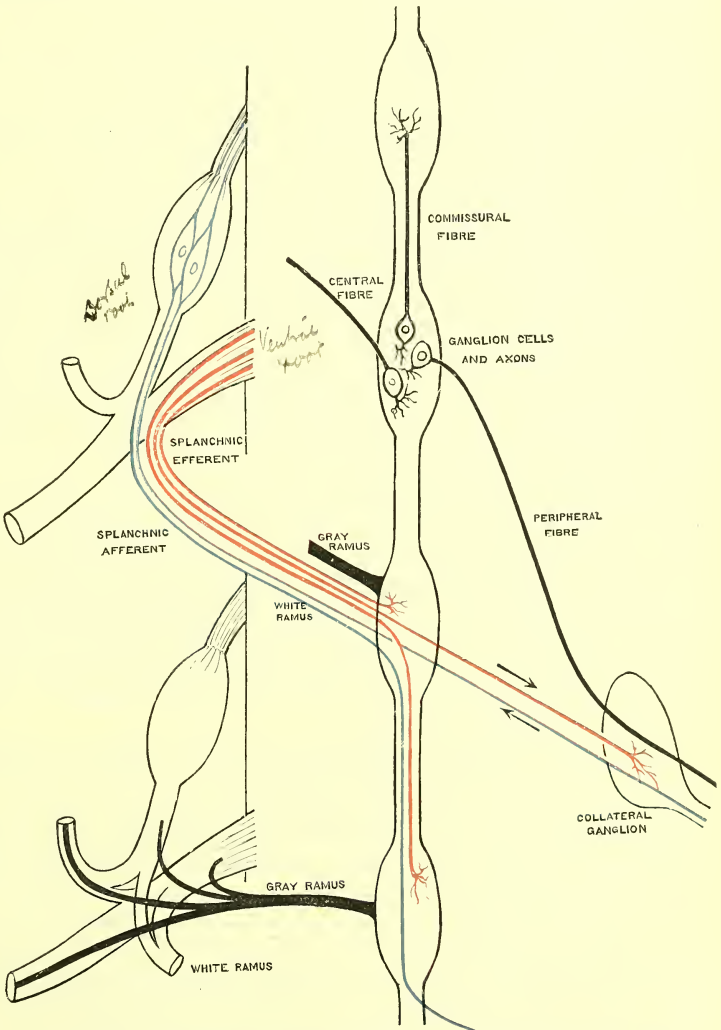


FIG. 541.—SCHEME OF THE CONSTITUTION AND CONNEXIONS OF THE GANGLIATED CORD OF THE SYMPATHETIC.

The gangliated cord is indicated on the right, with the arrangement of the fibres arising from the ganglion cells. On the left the roots and trunks of spinal nerves are shown, with the arrangement of the white ramus communicans above and of the gray ramus below.

The **commissural cords** of the sympathetic system are composed of white and gray fibres. The *white fibres* are: (1) splanchnic efferent fibres, passing to a ganglion above or below the point of entrance into the sympathetic system; (2) splanchnic afferent fibres, guided along the commissure and over or through the ganglia. The *gray fibres* are the axons of sympathetic ganglion cells: (1) true commissural fibres passing into connexion with the cells of a neighbouring ganglion; (2) fibres passing along the commissure for a certain distance upwards or downwards before entering the splanchnic area as peripheral branches.

The **peripheral (splanchnic) branches** from the sympathetic cord consist of—(1) white fibres—splanchnic afferent fibres unconnected with cells, and splanchnic efferent fibres which, after passing over the gangliated cord, are on their way to join peripheral (collateral) or terminal ganglia in relation to the viscera; and of (2) gray fibres, splanchnic efferent branches, the axons of sympathetic ganglion cells distributed to the vessels and viscera in the splanchnic area.

THE CERVICAL PART OF THE SYMPATHETIC CORD.

The cervical part of the sympathetic cord may be regarded as an upward prolongation of the primitive sympathetic system along the great vessels of the neck. It is characterised by the absence of **white rami communicantes** connecting it with the cervical spinal nerves. Its spinal fibres ascend in the commissural cord from the upper thoracic nerves to be connected with the cells of the cervical ganglia. The branches from the ganglia in the neck are distributed to structures in the head, neck, and thorax: (1) motor fibres to involuntary muscles (*e.g.* dilator of the pupil); (2) vaso-motor fibres along the arteries of the head and neck and upper limbs; (3) pilo-motor fibres along the cervical spinal nerves to the skin of the head and neck; (4) cardio-motor fibres; (5) and secretory fibres (for the submaxillary gland).

The gangliated cord in the neck is placed upon the prevertebral muscles and behind the carotid vessels. It extends from the root of the neck, where it is continuous behind the subclavian artery with the thoracic portion of the cord, to the base of the skull, where it ends in the formation of plexiform branches upon the internal carotid artery. It consists of a narrow commissural cord composed of medullated and non-medullated fibres, on which are two or three ganglia—a superior ganglion at the upper end, an inferior ganglion at the point of junction with the thoracic portion of the cord, and an intermediate middle ganglion varying in position and often absent.

The **superior cervical ganglion** (g. cervicale superius) situated at the base of the skull, lies between the internal jugular vein and the internal carotid artery. It is the largest of the sympathetic ganglia, measuring an inch or more in length. The commissural cord connects it with the **middle ganglion** (g. cervicale medium), which is of small size, is frequently absent, and may be divided into two parts. It is usually placed over the inferior thyroid artery as it passes behind the carotid sheath.

The **inferior ganglion** (g. cervicale inferius) is joined by the commissural cord to the middle (or superior) ganglion above, and is only imperfectly separated from the first thoracic ganglion below. It is of considerable size, irregular in shape, and is placed behind the first part of the subclavian artery in the interval between the last cervical transverse process and the neck of the first rib.

The **branches** from the cervical sympathetic ganglia and cord are divisible into two sets—(*A*) Central communicating branches for other nerves; (*B*) peripheral branches of distribution, which alone, or along with other nerves, form plexuses, accompanying and supplying vessels and viscera of the head, neck, and thorax. Although this distinction is made, it is to be borne in mind that the branches of communication are as much nerves of distribution as the others.

Superior Cervical Ganglion.

Central Communicating Branches.—1. **Gray rami communicantes** pass from the ganglion to the anterior primary divisions of the first four cervical nerves.

2. **Communications with Cranial Nerves.**—Just outside the skull, in the deep

part of the neck, communicating branches pass to the following cranial nerves: (*a*) to the petrous ganglion of the glosso-pharyngeal and the ganglion of the root of the pneumogastric (n. jugularis); (*b*) to the ganglion of the trunk of the pneumogastric; (*c*) to the hypoglossal nerve.

Peripheral Branches of Distribution.—1. Pharynx.—A **pharyngeal branch** courses downwards and inwards behind the carotid sheath to reach the wall of the pharynx, where it joins (along with the pharyngeal branches of the glosso-pharyngeal and pneumogastric nerves) in the formation of the **pharyngeal plexus**, and assists in supplying the muscles and mucous membrane of the pharynx.

2. Heart.—The **superior cervical cardiac** branch is a slender nerve which, on the *right side*, descends behind the large vessels into the thorax to join the deep cardiac plexus. On the *left side* the course of the nerve is similar in the neck, but in the superior mediastinum it passes between the left carotid and subclavian arteries, and over the aortic arch, to join with the inferior cervical cardiac branch of the pneumogastric in the formation of the superficial cardiac plexus. In their course both nerves form connexions with the other cervical cardiac nerves of the sympathetic, and with cardiac and other branches of the pneumogastric (external and inferior laryngeal).

3. Vessels.—(*a*) The **external carotid branch** passes forwards to the external carotid artery, and forms the **external carotid plexus**, which supplies offsets to that artery and its branches, as well as to the inter-carotid body. From the subordinate plexuses on the facial and middle meningeal arteries sympathetic fibres are supplied to the submaxillary and otic ganglia respectively.

(*b*) The **internal carotid branches** form an upward prolongation of the ganglion, which applies itself in the form of bundles of nerve-fibres to the internal carotid artery as it enters the carotid canal in the temporal bone. The branches separate into outer and inner parts, which form plexuses investing the artery in the cranium. The outer division forms the lower or **carotid plexus** (pl. caroticus internus); the inner division gives rise to the upper or **cavernous plexus** (pl. cavernosus). Both plexuses supply offsets to the artery and its branches, and form communications with certain cranial nerves.

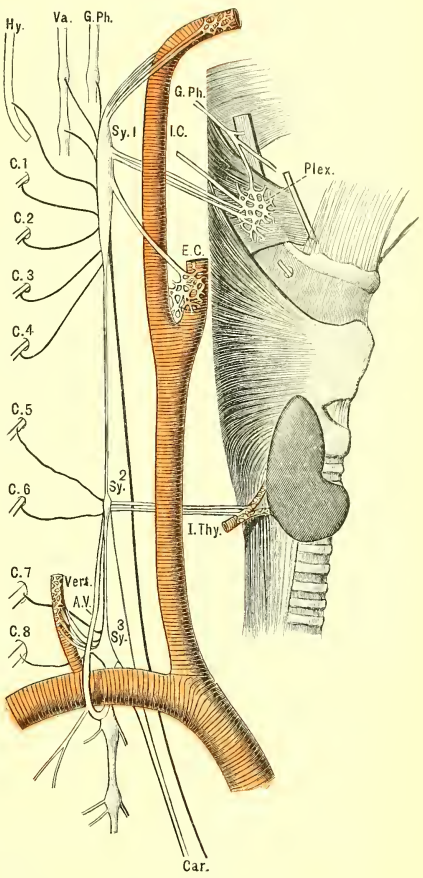


FIG. 542.—THE DISTRIBUTION OF THE SYMPATHETIC GANGLIATED CORD IN THE NECK.

Sy.1, Superior cervical ganglion, and connexions and branches; I.C, Internal carotid artery; G.Ph, Glosso-pharyngeal; Va, Vagus; Hy, Hypoglossal; C.1, 2, 3, 4, First four cervical nerves; Plex, Pharyngeal plexus; G.Ph, Glosso-pharyngeal nerve; E.C, To external carotid artery; Sy.2, Middle cervical ganglion, connexions, and branches; C.5, 6, Fifth and sixth cervical nerves; I.Thy, Inferior thyroid artery; A.V, Ansa Vieussenii; Sy.3, Inferior cervical ganglion, connexions, and branches; C.7, 8, Seventh and eighth cervical nerves; Vert, Vertebral plexus; Car, Cardiac branches.

The **carotid plexus** communicates by fine branches with (*a*) the abducent nerve, and (*b*) the Gasserian ganglion, and gives off (*c*) the great deep petrosal and (*d*) the small deep petrosal nerves. The **great deep petrosal nerve** joins the great superficial petrosal nerve from the geniculate ganglion of the facial, over the foramen lacerum medium. By their union the **Vidian nerve** is formed, which, after traversing the Vidian canal, ends in Meckel's ganglion. The **small deep petrosal nerve** passes to the **tympanic plexus**. This plexus, formed by the small deep petrosal nerve, the tympanic branch of the glosso-pharyngeal, and a twig

from the geniculate ganglion of the facial nerve, is placed on the inner wall of the tympanum. It supplies the mucous lining of the tympanum and Eustachian tube; and the **small superficial petrosal** nerve passes from it to the otic ganglion.

The **cavernous plexus** communicates with (*a*) the oculo-motor, and (*b*) the trochlear nerves, and (*c*) the ophthalmic division of the trigeminal nerve; it also (*d*) supplies twigs to the pituitary body, and (*e*) forms the sympathetic root of the ciliary ganglion. This may pass to the ganglion independently, or it may be incorporated in the long root of the ganglion from the nasal branch of the ophthalmic nerve.

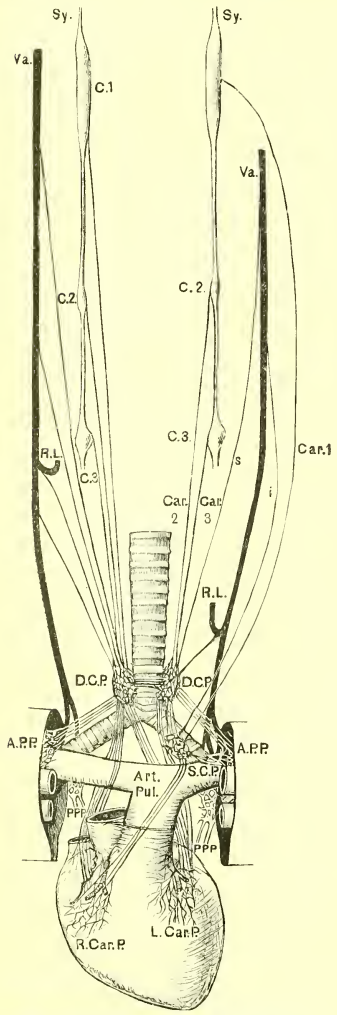


FIG. 543.—THE CONSTITUTION OF THE CARDIAC PLEXUSES.

Sy, Cervical sympathetic cord; C.1, Superior, C.2, Middle, and C.3, Inferior cervical ganglia; Car. 1, Superior, Car. 2, Middle, and Car. 3, Inferior cervical cardiac sympathetic branches; Va, Pneumogastric nerve; R.L, Recurrent laryngeal nerve; s, Superior, and i, Inferior cervical cardiac branches of vagus; D.C.P, Deep cardiac plexus; S.C.P, Superficial cardiac plexus; A.P.P, Anterior pulmonary plexus; P.P.P, Posterior pulmonary plexus; R.Car.P, Right, and L.Car.P, Left coronary plexuses; Art.Pul, Pulmonary artery.

MIDDLE CERVICAL GANGLION.

Central Communicating Branches.—1. **Gray rami communicantes** arise from the ganglion or from the cord for the anterior primary divisions of the fifth and sixth cervical nerves. 2. The subclavian loop (**ansa Vieussenii**) is a loop of communication from this ganglion, which, after passing over and supplying offsets to the subclavian artery and its branches, joins the inferior cervical ganglion.

Peripheral Branches of Distribution.—1. **Heart.**—A slender **middle cervical cardiac branch** descends, either separately or in company with other cardiac nerves, behind the large vessels into the thorax, where it ends in the deep part of the cardiac plexus on each side.

2. **Thyroid Body.** — Branches extend inwards along the inferior thyroid artery to supply the thyroid body.

When the middle ganglion is absent the branches described arise from the commissural cord.

INFERIOR CERVICAL GANGLION.

Central Communicating Branches.—1. **Gray rami communicantes** arise from this ganglion for the anterior primary divisions of the seventh and eighth cervical nerves. 2. The **subclavian loop** already mentioned connects the middle and inferior ganglia over the front of the subclavian artery. 3. A communication frequently occurs with the inferior laryngeal nerve.

Peripheral Branches of Distribution.—1. **Heart.**—An **inferior cervical cardiac branch** is given off on each side to enter the deep cardiac plexus.

2. **Vessels.**—(*a*) The **vertebral plexus** is a dense plexus of fibres surrounding the vertebral artery and accompanying its branches in the neck and the cranial cavity. (*b*) The **subclavian plexus** is derived from the subclavian loop, and supplies small offsets to the subclavian artery. It gives branches to the internal mammary artery, and communicates with the phrenic nerve.

THE THORACIC PART OF THE SYMPATHETIC CORD.

The thoracic part of the sympathetic cord consists of a variable number of ganglia of an irregularly angular or fusiform shape, joined together by commissural

cords of considerable thickness. The number of ganglia is usually ten or eleven; but the first and sometimes others may be so fused with the neighbouring ganglia as to still further reduce the number. This part of the sympathetic cord is characterised by its union with the thoracic spinal nerves. Each thoracic nerve, with the possible exception of the first, sends a **visceral branch** (white ramus communicans) to join the gangliated cord in the thorax. These white rami separate into two main streams in relation to the sympathetic cord. Those of the *upper five* nerves are for the most part directed upwards to be distributed through the cervical part of the sympathetic gangliated cord in the manner already described. The white rami of the *lower thoracic* nerves are for the most part directed downwards in the lower part of the sympathetic cord and its branches, to be distributed in the abdomen; at the same time some of their fibres are directly associated with the supply of certain thoracic viscera,—lungs, aorta, œsophagus.

These white rami are composed of (1) **splanchnic afferent fibres** passing from its peripheral branches through the sympathetic cord into the dorsal ganglia of the spinal nerves—medullated nerve-fibres unconnected with sympathetic ganglion cells; and (2) **somatic** and **splanchnic efferent fibres**, small medullated nerves which, after a longer or shorter course in the gangliated cord or its peripheral branches, become connected with the sympathetic ganglion cells, or with the cells of peripheral (collateral or terminal) ganglia, from which again (non-medullated) axons proceed to supply branches to viscera and vessels. The ultimate destination of the upper stream of white rami from the thoracic nerves has been mentioned in the description of the cervical sympathetic; the peripheral branches supplying thoracic organs contain vaso-motor fibres for the lungs and aorta. The peripheral branches from the lower part of the sympathetic cord in the thorax, receiving white rami from the lower thoracic nerves, are mainly destined for distribution to structures below the diaphragm. They comprise (*a*) viscero-inhibitory fibres for the stomach and intestines; (*b*) motor fibres for part of the rectum; (*c*) pilo-motor fibres for the lower part of the body; (*d*) vaso-motor fibres for the abdominal aorta and its branches, and

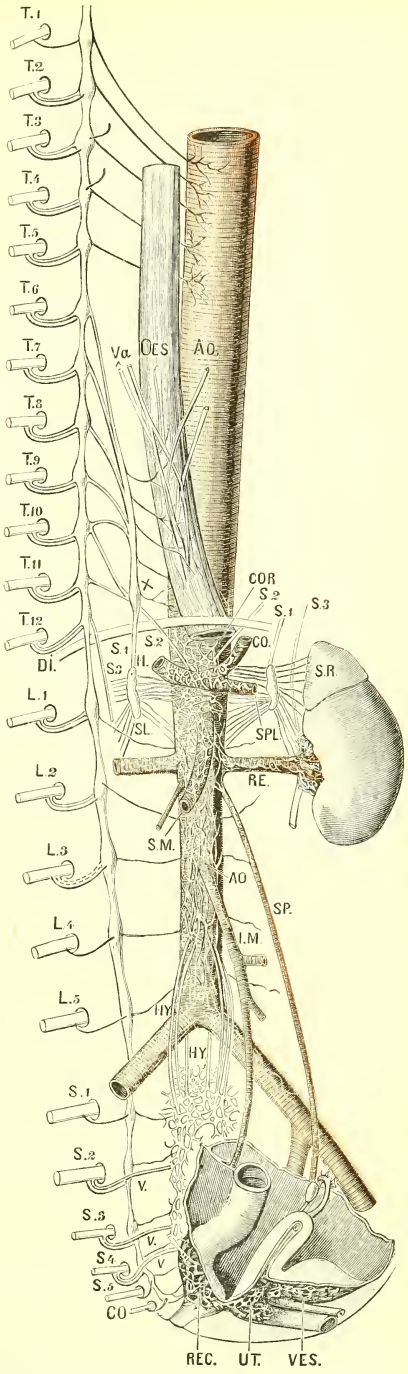


FIG. 544. — THE ARRANGEMENT OF THE SYMPATHETIC SYSTEM IN THE THORAX, ABDOMEN, AND PELVIS.

T.1-12; L.1-5; S.1-5; Co, Anterior primary divisions of spinal nerves, connected to the gangliated cord of the sympathetic by rami communicantes, white (double lines) and gray (single lines); OES, Œsophagus and œsophageal plexus; AO, Aorta and aorta plexus; Va, Vagus nerve joining œsophageal plexus; S.1, Great splanchnic nerve; X, Great splanchnic ganglion; S.2, Small splanchnic nerve; S.3, Least splanchnic nerve; Co, Coronary artery and plexus; SPL, Splenic artery and plexus; H, Hepatic artery and plexus; SL, Semilunar ganglion; Di, Diaphragm; S.R, Suprarenal capsule; RE, Renal artery and plexus; S.M, Superior mesenteric artery and plexus; SP, Spermatic artery and plexus; I.M, Inferior mesenteric artery and plexus; HY, Hypogastric nerves and plexus; REC, Rectal plexus; UT, Uterine plexus; VES, Vesical plexus; V.V.V, Visceral branches from sacral nerves.

for the lower limbs; (*e*) secretory, and (*f*) sensory fibres for the abdominal viscera. The thoracic part of the sympathetic cord is placed upon the heads of the ribs, and is covered over by the pleura.

The **branches** from the gangliated cord are, as in the neck, divisible into two sets—(*A*) Central branches, communicating with other nerves, and (*B*) peripheral branches, distributed in a plexiform manner to the thoracic and abdominal viscera.

Central Communicating Branches.—The **white rami communicantes** from the thoracic nerves have already been described. Passing forwards from the beginning of the anterior primary divisions of the nerves, they become connected with the ganglia or the commissural cord of the sympathetic.

The **gray rami communicantes** are branches arising irregularly from each thoracic ganglion, which, passing backwards along with the white rami, join the anterior primary divisions of the thoracic nerves.

Peripheral Branches of Distribution.—These branches arise irregularly from the ganglia and the commissural cord. They are composed of non-medullated fibres (splanchnic efferent) derived from the ganglion cells, and medullated fibres (splanchnic efferent and afferent) derived directly from the white rami, without the intervention of the cells of the ganglia.

1. **Pulmonary Branches.**—From the gangliated cord opposite the second, third, and fourth ganglia fine filaments arise which join the posterior pulmonary plexus.

2. **Aortic Branches.**—The upper part of the thoracic aorta receives fine branches from the upper five thoracic ganglia.

3. **Splanchnic Nerves.**—Three nerves arise from the lower part of the gangliated cord, partly from the ganglia themselves, and partly from the commissural cord between the ganglia. Passing downwards over the bodies of the thoracic vertebræ they pierce the diaphragm, to end in the abdomen.

(*a*) The **great splanchnic nerve** (n. splanchnicus major) arises from the gangliated cord between the fifth and ninth ganglia. By the union of several irregular strands a nerve of considerable size is formed, which descends in the posterior mediastinum, and piercing the crus of the diaphragm, joins at once the upper end of the *semilunar ganglion* of the solar plexus. In its course in the thorax the **great splanchnic ganglion** (g. splanchnicum) is formed upon the nerve. It is more prominent in the fœtus than in the adult. From both nerve and ganglion branches arise in the thorax for the supply of the œsophagus and descending thoracic aorta (Fig. 544).

(*b*) The **small splanchnic nerve** (n. splanchnicus minor) arises from the gangliated cord opposite to the ninth and tenth ganglia. It passes over the bodies of the lower thoracic vertebræ, pierces the diaphragm near or along with the great splanchnic nerve, and ends in the **solar plexus** (*aortico-renal ganglion*).

(*c*) The **least splanchnic nerve** (n. splanchnicus imus) arises from the last thoracic ganglion of the sympathetic, or it may be a branch of the smaller splanchnic nerve. It pierces the diaphragm, and ends in the *renal plexus*.

THE LUMBAR PART OF THE SYMPATHETIC CORD.

The lumbar part of the sympathetic cord is placed upon the bodies of the lumbar vertebræ, internal to the origins of the psoas muscle, and in front of the lumbar vessels. It is connected with the thoracic portion of the cord by an attenuated commissural cord, which either pierces or passes behind the diaphragm. It is continuous below with the sacral portion of the cord by a commissure, which passes behind the common iliac artery. It is joined by medullated fibres (white rami communicantes) from the first two lumbar spinal nerves, and it contains as well medullated fibres continued down from the lower part of the thoracic gangliated cord, and derived from the visceral branches (white rami communicantes) of the lower thoracic nerves. This part of the gangliated cord is characterised by great irregularity in the number of the ganglia. They are usually four in number, but there are frequently more (up to eight); and in extreme

cases fusion may occur to such an extent that the separation of individual ganglia becomes impossible.

White rami communicantes.—The first two (or three) lumbar spinal nerves possess visceral branches which form white rami communicantes joining the upper lumbar ganglia or the gangliated cord. These nerves form the lower limit of the thoracico-lumbar visceral branches of the spinal nerves. They comprise vaso-motor fibres (for the genital organs), and motor fibres for the bladder and uterus.

Central Communicating Branches. — **Gray rami communicantes** pass from the gangliated cord to the anterior primary divisions of the lumbar nerves in an irregular manner. One ramus may divide so as to supply branches to two adjacent spinal nerves; or a spinal nerve may be joined by two to five separate gray rami from the gangliated cord.

The rami course beneath the origin of the psoas magnus muscle and over the bodies of the vertebræ. Gray rami sometimes pierce the fibres of the psoas muscle.

Peripheral Branches of Distribution.—From the lumbar gangliated cord numbers of small branches arise irregularly, and pass inwards to supply the abdominal aorta, reinforcing the **aortic plexus** (from the solar plexus).

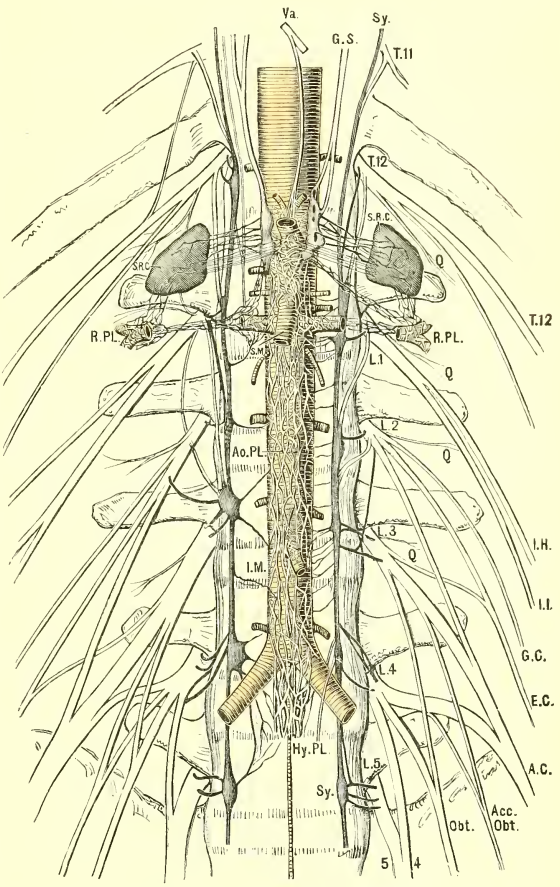


FIG. 545.—THE LUMBAR PORTION OF THE SYMPATHETIC GANGLIATED CORD AND LUMBAR PLEXUS. (From a dissection.)

T.11, T.12, L.1, L.2, L.3, L.4, L.5, Anterior primary divisions of spinal nerves, with white and gray rami communicantes.

Sy, Sympathetic gangliated cord; Va, Vagus nerve; G.S, Great splanchnic nerve, joining semilunar ganglion; S.R.C, Suprarenal capsule and plexus; R.Pl, Renal plexus; Ao.Pl, Aortic plexus; S.M, Superior mesenteric plexus; I.M, Inferior mesenteric plexus; Hy.Pl, Hypogastric plexus; Q, Nerves to quadratus lumborum; I.H, Ilio-hypogastric nerve; I.I, Ilio-inguinal nerve; G.C, Genito-crural nerve; E.C, External cutaneous nerve; A.C, Anterior crural nerve; Acc. Obt, Accessory obturator nerve; Obt, Obturator nerve 4, 5, Lumbo-sacral cord.

THE SACRAL PART OF THE GANGLIATED CORD.

The sacral part of the gangliated cord, like the cervical and lower lumbar portions of this system, receives no white rami communicantes from the spinal nerves. The **visceral branches** (*pelvic splanchnic*) of the third, and usually, also the second or fourth sacral nerves, enter the pelvic plexus without being directly connected with the gangliated cord. These nerves, however, are to be regarded as homologous with the white rami communicantes of the thoracico-lumbar nerves (*abdominal splanchnic*). They convey to the pelvic viscera—(1) motor and inhibitory fibres for rectum, uterus, and bladder, (2) vaso-dilator fibres for the genitals, and (3) secretory fibres for the prostate gland.

This portion of the cord is placed in front of the sacrum, internal to the anterior sacral foramina. It is connected above by a commissural cord with the lumbar portion of the sympathetic, and below it ends in a plexiform union over the coccyx with the cord of the other side, the two being frequently connected by the **ganglion impar** or **coccygeal ganglion.** The number of ganglia is variable; there are

commonly four. They are of small size, gradually diminishing from above downwards.

Central communicating branches arise irregularly in the form of **gray rami communicantes** from the sacral ganglia, and join the anterior primary divisions of the sacral and coccygeal nerves.

Peripheral Branches of Distribution.—(1) **Visceral branches** of small size arise from the upper part of the gangliated cord, and pass inwards to join the **pelvic plexus** (see below).

(2) **Parietal branches,** also of small size, ramify over the front of the sacrum, and form, in relation to the middle sacral artery, a plexiform union with branches from the gangliated cord of the other side.

SYMPATHETIC PLEXUSES.

It has already been seen that the peripheral branches of the sympathetic gangliated cord throughout its length are characterised by forming or joining plexuses in their neighbourhood.

The **cervical sympathetic ganglia** and nerves give rise to the carotid and cavernous plexuses; the external carotid, pharyngeal, thyroid, vertebral, and subclavian plexuses; and they send important branches to the cardiac plexuses (described along with the pneumogastric nerve).

The **thoracic ganglia** send branches to join the pulmonary and œsophageal plexuses (described along with the pneumogastric nerve). They form plexuses on the thoracic aorta, and by means of the splanchnic nerves they form the chief source of the solar plexus.

The Solar and Pelvic Plexuses.

These great plexuses serve to distribute nerves to the viscera and vessels of the abdominal and pelvic cavities. Taken together they include three plexuses—the solar plexus, hypogastric plexus, and the pelvic plexuses. They are constituted by peripheral branches of the lower thoracic, lumbar, and upper sacral parts of the gangliated cord of the sympathetic; and they are related to the central nervous system by means of the visceral branches (white rami communicantes) of the lower thoracic and upper lumbar nerves on the one hand, and by the visceral branches of the second and third, or third and fourth sacral nerves, on the other hand. The thoracico-lumbar series join the sympathetic cord, and reach the solar plexus mainly through the splanchnic nerves, and to a lesser extent through the lumbar gangliated cord. The sacral series enter the pelvic plexus without connexion with the sympathetic cord. The hypogastric plexus serves as a connecting link between the solar and pelvic plexuses.

The **solar plexus** lies on the posterior abdominal wall in relation to the abdominal aorta and behind the stomach. It is composed of three elements: the **cœliac plexus** surrounding the origin of the cœliac axis between the crura of the diaphragm, and two **semilunar ganglia,** each lying on the corresponding crus of the diaphragm, and overlapped by the suprarenal capsule, and on the right side by the inferior vena cava. The plexus is continuous with subordinate plexuses, diaphragmatic, suprarenal, renal, superior mesenteric and aortic; and by means of **the hypogastric nerves** the aortic plexus becomes continued into the **hypogastric plexus,** which again forms the chief origin of the **pelvic plexuses.**

The **semilunar ganglia** constitute the chief ganglionic centres in the solar plexus. They are irregular in form. They are often partially subdivided, and one detached portion at the lower end is named the **aortico-renal ganglion.** Other small scattered masses of cells are present in the cœliac plexus (**ganglia cœliaca**). At the upper end the semilunar ganglion receives the great splanchnic nerve. The aortico-renal ganglion at its lower end receives the smaller splanchnic nerve. Branches from the ganglion radiate in all directions—inwards to join the cœliac plexus, upwards to form the diaphragmatic plexus, outwards to the suprarenal plexus, downwards to the renal, superior mesenteric, and aortic plexuses.

The **cœliac plexus** forms a considerable plexiform mass surrounding the cœliac axis. It consists of a dense meshwork of fibres with ganglia intermingled (g. cœliaca), joined by numerous branches from the semilunar ganglion on each side, and by branches from the right pneumogastric nerve. It is continuous below with the superior mesenteric and aortic plexuses. Investing the cœliac axis, it forms subsidiary plexuses which accompany the branches of the artery. The **coronary plexus** supplies branches to the œsophagus and stomach; the **hepatic plexus** supplies branches to the liver and gall-bladder, stomach, duodenum, and pancreas; and the **splenic plexus** sends offsets to the spleen, pancreas, and stomach.

Subordinate plexuses are formed on the aorta and its branches by nerves derived from the solar plexus (semilunar ganglia and cœliac plexus).

a. The **diaphragmatic plexus** consists of fibres arising from the semilunar ganglion, and accompanies the inferior phrenic artery. Besides supplying the diaphragm, it gives branches to the suprarenal plexus, and (on the right side) to the inferior vena cava, (on the left side) to the œsophagus. It communicates on each side with the phrenic nerve. At the junction of the plexus and the phrenic nerve of the right side a ganglion is formed **(diaphragmatic ganglion)**.

b. The **suprarenal plexus** is of most considerable size. It is mainly derived from branches of the semilunar ganglion, reinforced by nerves from the lower part of the solar plexus which stream outwards on the capsular arteries. It is joined by branches from the diaphragmatic plexus above and from the renal plexus below. The nerves enter the substance of the suprarenal capsule.

c. The **renal plexus** is derived from (1) branches of the semilunar ganglion, and (2) fibres from the aortic plexus, extending outwards along the renal artery to the hilum of the kidney. It receives also the least splanchnic nerve, and is connected by numerous branches to the suprarenal plexus.

d. The **superior mesenteric plexus** is inseparable above from the cœliac plexus, and is joined on either side by fibres from the semilunar ganglion. It is continuous below with the aortic plexus. A separate detached ganglionic mass (**superior mesenteric ganglion**) is present in

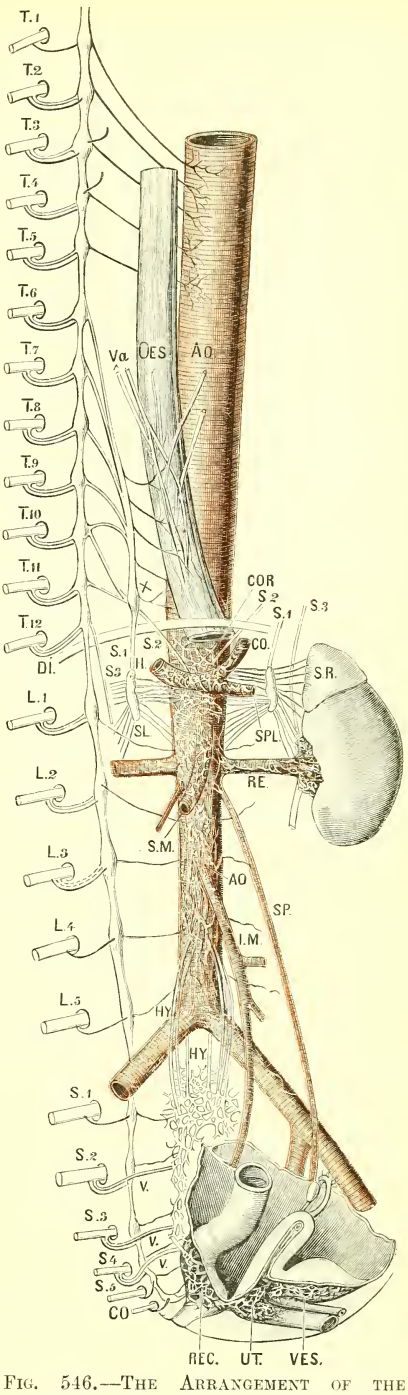


FIG. 546.—THE ARRANGEMENT OF THE SYMPATHETIC SYSTEM IN THE THORAX, ABDOMEN, AND PELVIS.

T.1-12; L.1-5; S.1-5; Co, Anterior primary divisions of spinal nerves, connected to the gangliated cord of the sympathetic by rami communicantes, white (double lines) and gray (single lines); OES, Œsophagus and œsophageal plexus; AO, Aorta and aortic plexus; Va, Vagus nerve joining œsophageal plexus; S.1, Great splanchnic nerve; X, Great splanchnic ganglion; S.2, Small splanchnic nerve; S.3, Least splanchnic nerve; CO, Coronary artery and plexus; SPL, Splenic artery and plexus; H, Hepatic artery and plexus; S.L, Semilunar ganglion; Di, Diaphragm; S.R, Suprarenal capsule; RE, Renal artery and plexus; S.M, Superior mesenteric artery and plexus; SP, Spermatic artery and plexus; I.M, Inferior mesenteric artery and plexus; HY, Hypogastric nerves and plexus; REC, Rectal plexus; UT, Uterine plexus; VES, Vesical plexus; V.V.V, Visceral branches from sacral nerves.

the plexus. Accompanying the superior mesenteric artery the plexus forms subordinate plexuses around the branches of the vessel. The plexuses in the mesentery at first surround the intestinal arteries, but near the intestine they form fine plexuses between the layers of the mesentery, from which branches pass to the wall of the gut. This plexus supplies the small intestine, cæcum, vermiform appendix, ascending and transverse portions of the colon.

e. The **aortic plexus** is the continuation downwards of the solar plexus around the abdominal aorta. It is continuous above with the superior mesenteric and solar plexuses; it is reinforced by the peripheral branches of the lumbar gangliated cord of the sympathetic; and it is connected with the hypogastric plexus below by the **hypogastric nerves**. Besides investing and supplying the aorta, the plexus contributes to various subordinate plexuses on the branches of the artery. It contributes to the suprarenal and renal plexuses, and it gives rise to the spermatic or ovarian and the inferior mesenteric plexuses.

The **spermatic plexus** invests and accompanies the spermatic artery. It is derived from the aortic plexus, and receives a contribution from the renal plexus. It supplies the spermatic cord and testicle.

The **ovarian plexus** in the female arises like the spermatic plexus. It accompanies the ovarian artery to the pelvis, and supplies the ovary, broad ligament, and Fallopian tube. It forms communications in the broad ligament with the **uterine plexus** (from the pelvic plexus), and sends fibres to the uterus.

The **inferior mesenteric plexus** is a derivative from the aortic plexus, prolonged along the inferior mesenteric artery. It forms subordinate plexuses on the branches of the artery (colic, sigmoid, and superior hæmorrhoidal), and is distributed to the descending colon, iliac colon, pelvic colon, and upper part of the rectum.

The **hypogastric nerves** form the continuation of the aortic plexus into the pelvic cavity. They consist of numerous plexiform bundles of nerve-fibres which descend along the front and back of the bifurcation of the aorta and the origin of the common iliac arteries, and over the sacral promontory, where, becoming inextricably mingled, they constitute the hypogastric plexus.

The **hypogastric plexus** is continued downwards in front of the sacrum on either side of the rectum, and ends in the pelvic plexuses.

The **pelvic plexuses** are formed by the separation of the hypogastric plexus into two halves on either side of the rectum. Each is joined by fibres from the upper part of the sacral portion of the gangliated cord of the sympathetic, and by the **visceral branches** (white rami communicantes) from the second and third or third and fourth sacral nerves. Accompanying the internal iliac artery and its branches each pelvic plexus gives off subordinate plexuses for the pelvic viscera.

a. The **hæmorrhoidal plexus** supplies the rectum, and joins the superior hæmorrhoidal plexus from the inferior mesenteric plexus.

b. The **vesical plexus** accompanies the vesical arteries to the bladder-wall. Besides supplying the muscular wall and mucous membrane of the bladder, it forms subordinate plexuses for the lower part of the ureter, the vesicula seminalis, and the vas deferens.

c. The **prostatic plexus** is of considerable size. It is placed on either side of the gland, and in addition to supplying its substance and the prostatic urethra, it sends offsets to the neck of the bladder and the vesicula seminalis. It is continued forwards on each side to form the **cavernous plexus** of the penis (plex. cavernosus penis). Bundles of nerves pierce the layers of the triangular ligament, and after supplying the membranous urethra at the root of the penis, give off branches which enter and supply the corpus cavernosum. The cavernous nerves communicate with branches of the pudic nerve, and give offsets to the corpus spongiosum and the spongy portion of the urethra.

d. The **uterine plexus** passes upwards for a short distance with the uterine artery between the layers of the broad ligament, and is then distributed to the surfaces and substance of the organ. It communicates between the layers of the broad ligament with the ovarian plexus.

The **vaginal plexus** is formed mainly by the visceral branches of the sacral

nerves entering the pelvic plexus. It supplies the wall and mucous membrane of the vagina and urethra, and provides a **cavernous plexus** for the clitoris (plex. cavernosus clitoridis). The uterine and vaginal plexuses of the female correspond to the prostatic plexus of the male.

DEVELOPMENT OF THE SYMPATHETIC SYSTEM.

There are two diametrically opposite views of the mode of development of the sympathetic system.

In birds and mammals the first rudiment of the sympathetic cord occurs in the formation of a longitudinal unsegmented column of mesoblastic cells (which stain more deeply than the mesoblast in which they lie) on either side of the aorta, and coterminous with it. This column of cells becomes joined at an early stage by the **visceral branches** of the spinal nerves which grow inwards from the main nerve trunks into the splanchnic area, and result from the division of the nerve into somatic and visceral parts. These visceral branches constitute the **white rami communicantes**. They receive contributions usually from both dorsal and ventral roots, and gradually approaching the above-mentioned column of mesoblastic cells, they become intimately associated with the cells. In some cases fibres of the visceral nerves pass over the cellular column into the splanchnic area without connexion with it (Fig. 548). By the junction of these visceral nerves with the cells of the column, certain cells persist and produce the **ganglia**. The intervening portions of the column, by changes in the cells, and by the addition possibly of fibres belonging to the visceral nerves, give rise to the **commissural cords**. The cellular column, besides producing the gangliated cord, by the further growth of its cells and their extension centrally and peripherally, produces the **gray rami communicantes**, parts of the **peripheral branches**, and the **peripheral** (collateral and terminal) **ganglia**, as well as the medullary portion of the **suprarenal capsule**. The cervical, lower lumbar, and sacral portions of the sympathetic gangliated cord are secondary extensions from the more primitive condition, gradually growing upwards and downwards along the main vessels. These portions of the system are not provided with white rami communicantes. The ganglia of the sympathetic assume their segmented appearance (1) from the persistence of the primitive cells and their connexion with the spinal nerves by means of the white and gray rami communicantes, and (2) from the way in which the primitive column is moulded by the surrounding structures (bones, segmental arteries, etc.)

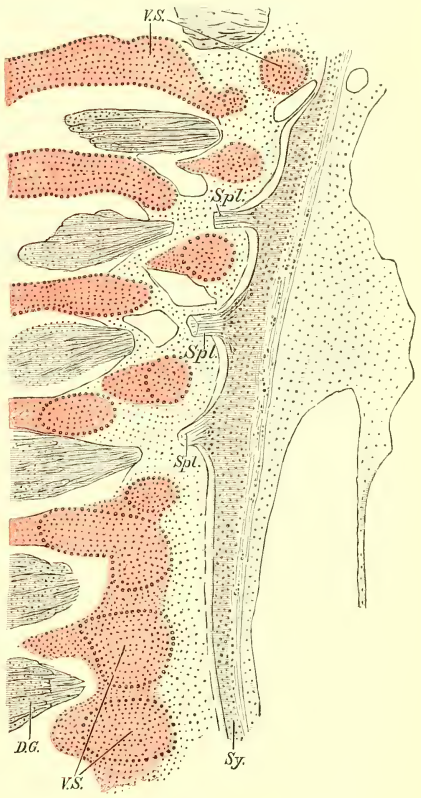


FIG. 547.—THE DEVELOPMENT OF THE SYMPATHETIC GANGLIATED CORD.

Sy, Sympathetic cord; Spl, Splanchnic branches of spinal nerves (white rami communicantes); V.S, Vertebral segments; D.G, Dorsal ganglia.

Another account of the development of the sympathetic system, supported by high authority, describes the gangliated cord as an outgrowth of the dorsal ganglia of the spinal nerves. It is said that each ganglion gives off a bud at its lower end, which, growing inwards into the splanchnic area, becomes attached to the trunk of the spinal nerve just beyond the union of the dorsal and ventral roots. The bud still extending inwards into the splanchnic area, remains associated with the nerve by an attenuated stalk. These buds, it is said, become the ganglia, which, after reaching their permanent place in the splanchnic area, are supposed to extend upwards and downwards so as to coalesce and form a beaded chain of ganglia. The stalks connecting the ganglia with the spinal nerves become the white rami communicantes. This mode of development does not satisfactorily account for several important features of the sympathetic system—the development of those parts of the gangliated cord which possess no white rami, the

absence of a real segmental character in the cord (remarkably shown in the fœtus), and the constancy of continuity in the gangliated cord. No instance is recorded of a hiatus between two ganglia. It is a tempting view on the other hand, as it ascribes to the one germinal layer (epiblast) the formation of all the elements of the nervous system, and it brings the sympathetic ganglia into serial homology with isolated ganglia on the cranial nerves (*e.g.* the ciliary, spheno-palatine, and otic, on the trigeminal nerve).

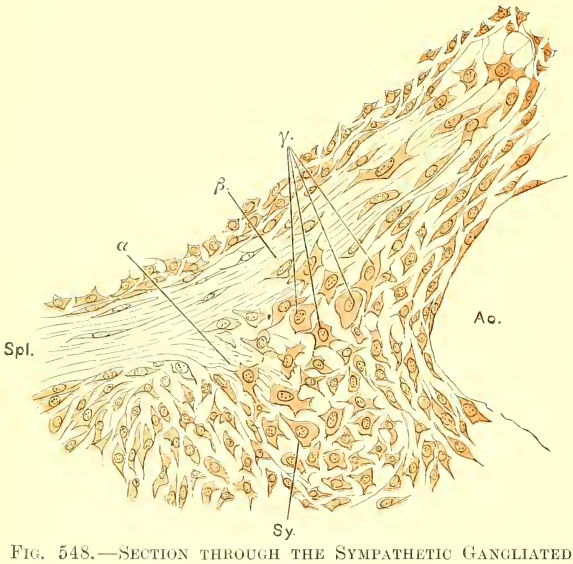


FIG. 548.—SECTION THROUGH THE SYMPATHETIC GANGLIATED CORD OF AN EMBRYO.

Showing the connexion with the ganglion (Sy) of the white ramus communicans (Spl); (α) a portion of the ramus joining the ganglion; (β) fibres passing over the cord, accompanied by a stream of cells; (γ) continuous with those of the ganglion; (Ao) Aorta.

The Morphology of the Sympathetic System.

From a consideration of its structure, functions, and development, there appear to be two separate structures represented in the sympathetic nervous system—the **spinal** and the **sympathetic elements**. The structure of the system presents a union of two distinct elements—fibres of cerebro-spinal origin and "sympathetic" cells and fibres. While the function of the gangliated cord and its branches seems to be absolutely dependent upon the cerebro-spinal nervous system, it is certain that the cells and fibres of the sympathetic system possess a vital activity apart from their connexion with the central nervous system. In the development of the sympathetic it is at least highly probable that a mesoblastic rudiment or precursor forms the basis of the sympathetic system, which is secondarily joined by nerve-fibres from the roots of the spinal nerves.

Morphologically this part of the nervous system is essentially a longitudinal cord or column, associated with involuntary muscles and glandular tissues, and particularly related to the organs in the splanchnic area. Like other longitudinal structures in the body, and especially like the organs of the splanchnic area, the sympathetic system is not truly segmental. The gangliated cord is only quasi-segmental, the segmentation being attributable to its junction with the visceral branches of the spinal nerves. The peripheral branches from the gangliated cord are not segmental; even the gray rami are not properly metameric, but, like the ganglia, assume a segmental character in consequence of their connexions with the spinal nerves.

The phylogenetic relation of the sympathetic and the cerebro-spinal elements in the system it is impossible to determine. It may be that the sympathetic system is the representative of an ancient architecture independent of the cerebro-spinal nervous system, the materials of which are utilised for a more modern nervous system; or it may be that the correlation of spinal nerves and sympathetic are both the consequences of the formation of new organs and structures in the splanchnic area. Examined in every light, it possesses features which effectually differentiate it from the cerebro-spinal system, although it has become inextricably united with it and subservient to it.

THE ORGANS OF SENSE AND THE INTEGUMENT.

By Robert Howden.

THE NOSE.

The nose constitutes the peripheral part of the organ of smell (organon olfactus), since to the upper portion of its mucous lining the branches of the olfactory nerve are distributed. It consists of an external portion, the outer nose, which projects from the face, and of an internal part, or cavum nasi, which is divided by a vertical septum into right and left cavities or fossæ.

The **outer nose**, or nasus externus, forms a more or less triangular pyramid, of which the upper angle is termed the **root** (radix nasi), and is usually separated from the glabella by a depression, while its **base** (basis nasi), directed downwards, is perforated by the apertures of the nostrils (anterior nares). Its free angle is named the **point** (apex nasi), and the anterior border, joining root and point, is termed the **dorsum nasi**; the upper part of the dorsum is supported by the nasal bones, and is named the **bridge**. The lateral aspects of the nose are continuous with the eyelids above and with the cheeks below, forming with the latter a varying angle. Each lateral surface ends inferiorly in a mobile and expanded portion, the **ala nasi**, which forms the outer boundary of the anterior nares, and is limited above by a furrow, the **alar sulcus**. The skin covering the nose is thin and movable over the root, but thick and adherent over the point and alæ, where it contains numerous large sebaceous glands.

The arterial supply of the outer nose is derived from the facial and ophthalmic arteries, and its veins drain themselves into the facial and ophthalmic trunks. Its principal lymphatic vessels follow the course of the facial vein and open into the submaxillary lymphatic glands. From the root of the nose one or two vessels curve backwards above the orbit to reach the upper parotid glands, while a third group runs below the orbit to the lower parotid glands. The facial nerve supplies its muscles, while the sensory nerves for the skin are the infratrochlear and nasal branches of the ophthalmic nerve and the infraorbital branch of the superior maxillary nerve.

The nose presents great variety as to its size and shape, and certain well-defined types, such as aquiline, Grecian, etc., are described. The relation which its breadth, measured across the alæ, bears to its length, measured from root to point, is termed the nasal index, and is expressed thus:

$$\frac{\text{greatest breadth} \times 100}{\text{greatest length.}}$$

In white races this index is below 70 (leptorhines); in yellow races, between 78 and 85 (mesorhines); and in black races, above 85 (platyrhines).

CARTILAGES OF THE NOSE.

In addition to the bony skeleton of the nose there are five chief cartilages (cartilagines nasi) which contribute to the production and maintenance of its shape. These are named—(*a*) the cartilage of the septum, and (*b*) the upper and lower lateral cartilages on each side.

The **cartilage of the septum** (cartilago septi nasi, Fig. 549) is of an irregularly quadrilateral form. Its postero-superior edge is attached to the mesethmoid; its postero-inferior margin to the vomer and intermaxillary crest. Its antero-superior

border is thick, and is fixed above to the back of the internasal suture; below the level of the nasal bones it is continued, on either side, into the upper lateral cartilages, which may be looked upon as its wing-like expansions. The lower part

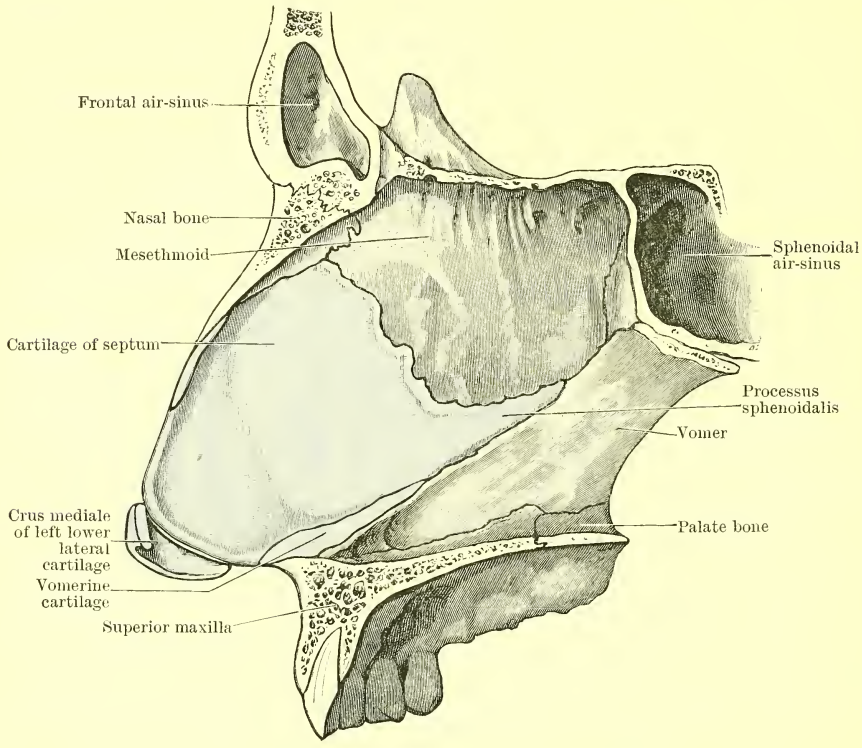


Fig. 549.—Lateral View of Nasal Septum.

of this border is separated by a fissure from the upper lateral cartilages, and extends downwards between the inferior lateral cartilages, to which it is attached by fibrous tissue. In this fibrous tissue a small sesamoid cartilage is usually seen on each side of the middle line. Its antero-inferior border is short, and is attached by fibrous tissue to the mesial plates of the lower lateral cartilages, while its anterior angle is rounded and does not reach as far as the point of the nose. The lowest part of the nasal septum is not formed by the septal cartilage, but by the mesial plates of the lower lateral cartilages and by the integument, and, being freely movable, is termed the **septum mobile nasi**. The cartilage of the septum may be prolonged backwards (especially in children) as a tongue-like process into the angle between the vomer and ethmoid. This process, varying in width from 4-6 mm., is named the **processus sphenoidalis septi cartilaginei**, and sometimes reaches as far as the body of the sphenoid.

Lying along the lower edge of the cartilage of the septum, and best seen on making a coronal section of the nose, are a couple of elongated cartilaginous strips. Each measures from 6-12 mm. in length, is attached to the vomer, and is named the **vomerine cartilage** (cartilago vomeronasalis, Jacobsoni).

The **upper lateral cartilage** (cartilago nasi lateralis, Figs. 550, 551) is triangular in shape and situated immediately below the nasal bone, to which and to the superior maxilla its thin posterior border is attached. Its anterior edge is thick and its upper part is directly continuous with the cartilage of the septum. Its lower margin is joined by fibrous tissue to the upper edge of the lower lateral cartilage.

The **lower lateral cartilage** (cartilago alaris major, Figs. 550, 551, 552) encircles the anterior part of the nostril and assists in keeping it open. It consists of two plates, outer and inner, which are continuous with each other in a rounded angle at the point of the nose. The **outer plate**, or crus laterale, is oval in shape and is attached to the upper lateral cartilage and to the superior maxilla by fibrous tissue.

Continuous with its postero-superior angle are two or three small cartilaginous pieces (cartilagines alares minores), while sometimes a horizontal furrow cuts off a narrow linear part from its upper aspect. The lower edge of the outer plate does not descend as far as the lateral boundary of the nostril, the ala being devoid of cartilage and composed merely of fatty and connective tissue covered by skin. The **inner plate**, or crus mediale (Fig. 552), bounds the inner aspect of the nostril and lies in the septum mobile nasi, below the anterior part of the cartilage of the septum. The mesial plates of the two cartilages are separated in front by a notch which corresponds with the point of the nose, and each curves slightly outwards posteriorly and ends in a rounded extremity.

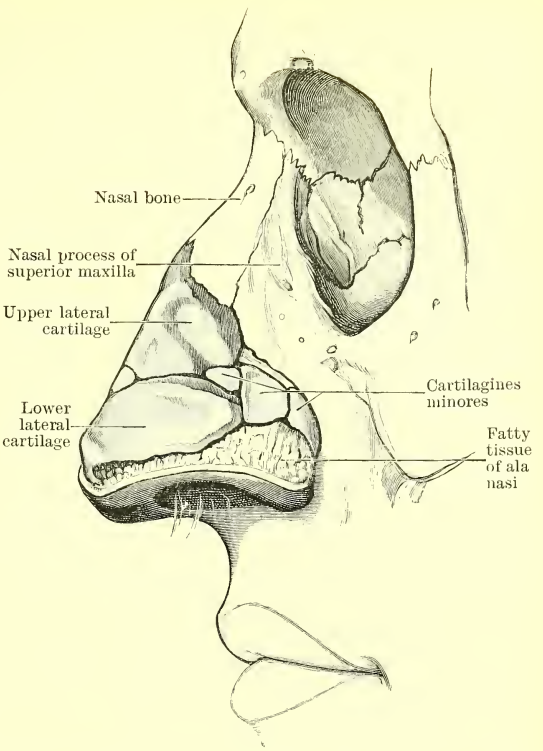


Fig. 550.—Profile View of the Bony and Cartilaginous Skeleton of the Nose.

NASAL FOSSÆ.

The **nasal fossæ** (Fig. 553) are two in number and are placed one on either side of the middle line. They extend from the anterior to the posterior nares or choanæ, and open through the latter into the naso-pharynx. Their bony boundaries are described in the section on Osteology (p. 173). On the lateral wall of each are found the orifices of the frontal, ethmoidal, sphenoidal, and maxillary sinuses, together with that of the nasal duct.

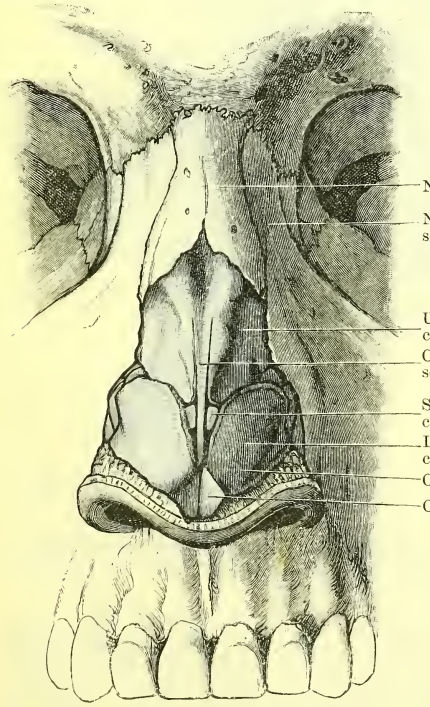


Fig. 551.—Front View of the Bony and Cartilaginous Skeleton of the Nose.

Immediately above the aperture of the nostril is a slightly expanded area, the **vestibule** (vestibulum nasi). This is bounded externally by the lower lateral cartilage, and, internally, by the lower part of the septum, and is prolonged towards the tip of the nose as a small pouch, termed the **ventricle**. Partly subdivided by a curved ridge, the vestibule is lined by skin and contains hairs and sebaceous glands. The hairs, or vibrissæ, springing from its lower half, are stout and curved downwards to guard the entrance to the nostril. The upper part of the vestibule is smooth, and is limited above and behind by a slightly-marked arched prominence, the **limen nasi**, beyond which the fossa is lined by mucous membrane.

The nasal fossa above and behind the vestibule is divided into two parts, viz. an upper or olfactory, and a lower or respiratory region. The **olfactory part**, or regio olfactoria, is a narrow, slit-like cavity, and comprises the region of the superior turbinated bone, together with a corresponding portion of the septum. The **respiratory part**, or regio respiratoria, is expanded, and includes the lower and remaining parts of the fossa.

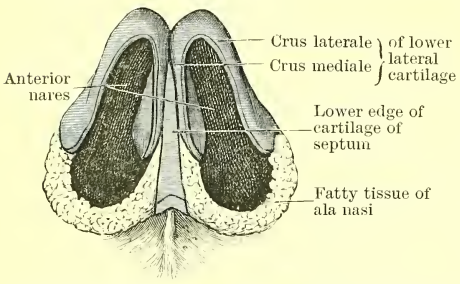


FIG. 552.—CARTILAGES OF NOSE FROM BELOW.

Inner Wall or Septum Nasi (Fig. 549).—Where the bony septum is deficient, below and in front, the gap is filled by the septal cartilage. Until the seventh year the nasal septum lies, as a rule, in the mesial plane, but after this age is very often deflected to one or other side—more frequently to the right—the deflection being usually greatest along the line of junction of the vomer and mesethmoid. Deflection of the septum is more common in European than in non-European skulls—occurring in about 53 per cent of the former and in about 28 per cent of the latter (Zuckerkandl, *Anatomie der Nasenhöhle*, 1892). Associated with, or apart from, this deviation, lateral crests or spurs of bone are found, in about 20 per cent of skulls, projecting from the septum into one or other nasal fossa. In the floor of the fossa, close to the lower edge of the septal cartilage and immediately over the incisive foramen, a slight depression, the **recessus naso-palatinus**, may be seen. It is directed downwards and forwards, and indicates the position of the communication which originally existed between the nasal and buccal cavities. In the septum, a little above and in front of this depression, is a minute orifice, not always recognisable, from which a blind pouch extends upwards and backwards for a distance of from 2 to 9 mm. This is the rudimentary **organ of Jacobson** (organon vomeronasale) and is supported by the vomerine cartilage. In many of the lower animals this organ is well developed (Fig. 554), and probably plays a part in the sense of smell, being lined by epithelium similar to that in the olfactory part of the nose and supplied by branches of the olfactory nerve.

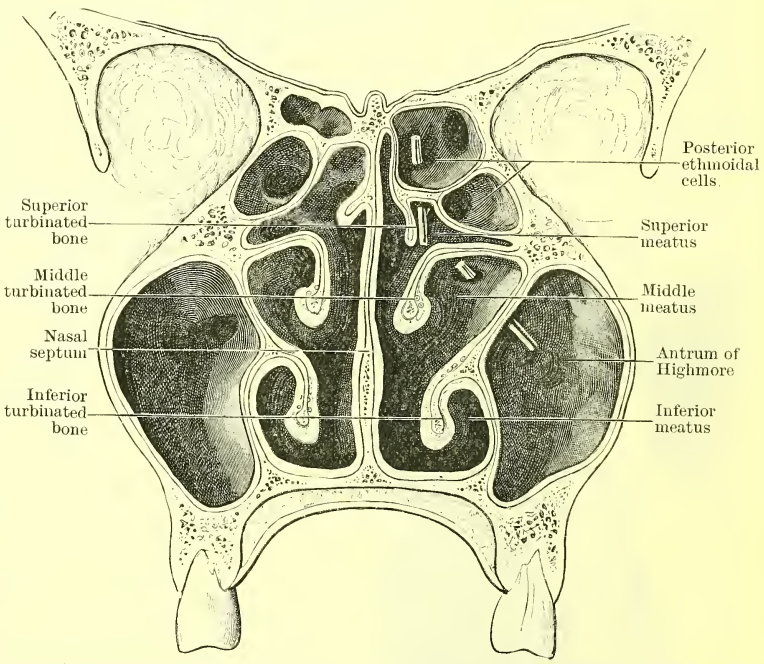


FIG. 553.—CORONAL SECTION THROUGH NASAL FOSSÆ; ANTERIOR HALF OF SECTION VIEWED FROM BEHIND.

Outer Wall (Fig. 555).—Above the superior turbinated bone is a narrow recess, the **recessus spheno-ethmoidalis**, into the posterior part of which the sphenoidal air-sinus opens. The **superior meatus** (meatus nasi superior) is a short oblique fissure, directed downwards and backwards under cover of the superior turbinated bone; into its antero-superior portion the posterior ethmoidal cells open by one or more orifices.

The narrow slit-like interval between the nasal septum and the inner aspect of the middle turbinated bone is named the **olfactory cleft** or **sulcus**. The **middle meatus** (meatus nasi medius), situated below and to the outer side of the middle turbinated bone, is a roomy passage, and is continued forwards into a slightly depressed area termed the **atrium meatus nasi**, which lies immediately above the vestibule. The atrium is limited above and in front by a low ridge, the **agger nasi**, the representative of the naso-turbinal found in many animals. On raising or removing the middle turbinated bone a rounded elevation, **bulla ethmoidalis**, caused by the middle ethmoidal air-cells, is seen. This varies in size and is directed downwards and forwards, whilst opening either on it or above it are the orifices of the middle ethmoidal cells. Curving upwards and forwards, below and in front of the bulla ethmoidalis, is a deep, narrow groove, the **hiatus semilunaris**, into which the anterior ethmoidal cells and the antrum of Highmore open. The opening from the antrum (ostium maxillare) is situated near the lower and back part of the hiatus, and is placed near the

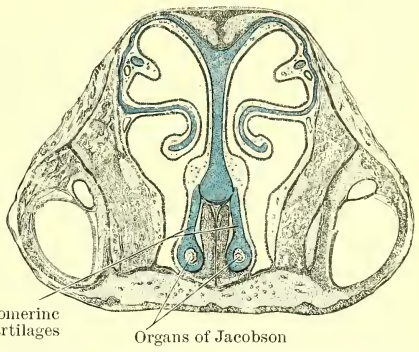


FIG. 554.—SECTION THROUGH NOSE OF KITTEN, showing position of Jacobson's organ.

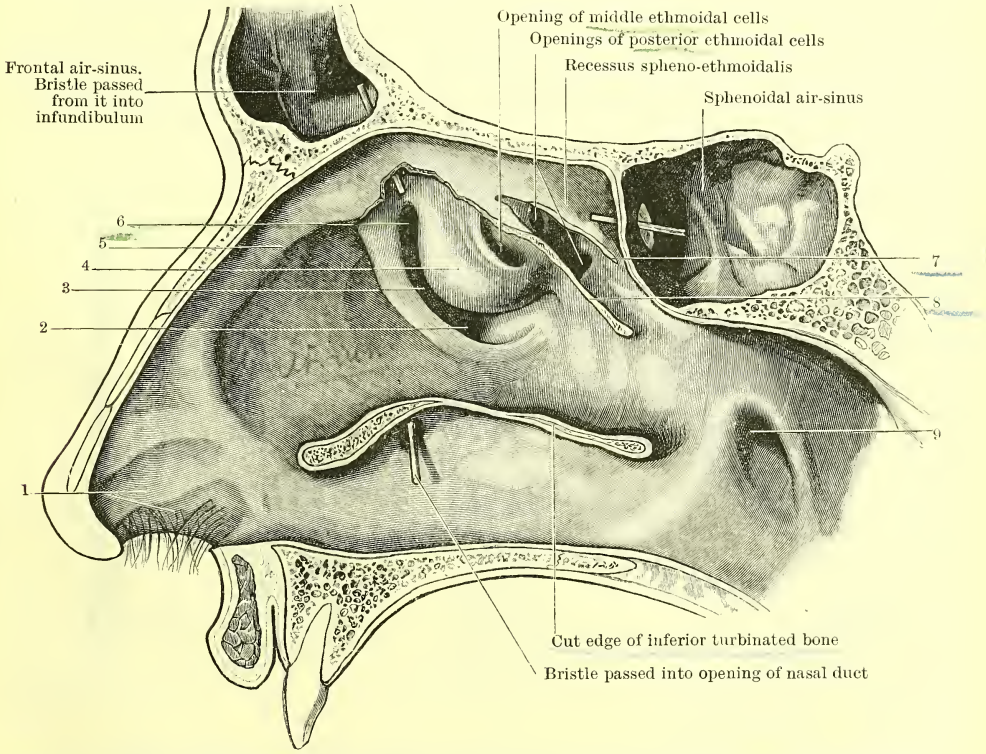


FIG. 555.—VIEW OF THE OUTER WALL OF THE NOSE—THE TURBINATED BONES HAVING BEEN REMOVED.

1. Vestibule.
2. Opening of antrum of Highmore.
3. Hiatus semilunaris.
4. Bulla ethmoidalis.
5. Agger nasi.
6. Opening of anterior ethmoidal cells.
7. Cut edge of superior turbinated bone.
8. Cut edge of middle turbinated bone.
9. Pharyngeal orifice of Eustachian tube.

roof of the antral cavity. A second opening (ostium accessorium) is not infrequently seen in the middle meatus above the posterior part of the inferior turbinated bone. The middle meatus extends upwards and forwards, and, becoming narrowed, is continued into the **infundibulum** or channel leading into the frontal air-sinus. The **inferior meatus** (meatus nasi inferior) lies below the inferior turbinated bone,

under cover of the anterior part of which is found the slit-like orifice of the nasal duct (see p. 741).

Mucous Membrane (membrana mucosa nasi).—The Schneiderian or nasal mucous membrane is thick, highly vascular, and firmly bound to the subjacent periosteum and perichondrium. It is continuous, through the choanæ, with the mucous lining of the naso-pharynx; through the nasal duct and lachrymal canals, with the conjunctiva; and, through the apertures leading into the air-sinuses, with the delicate lining of these cavities.

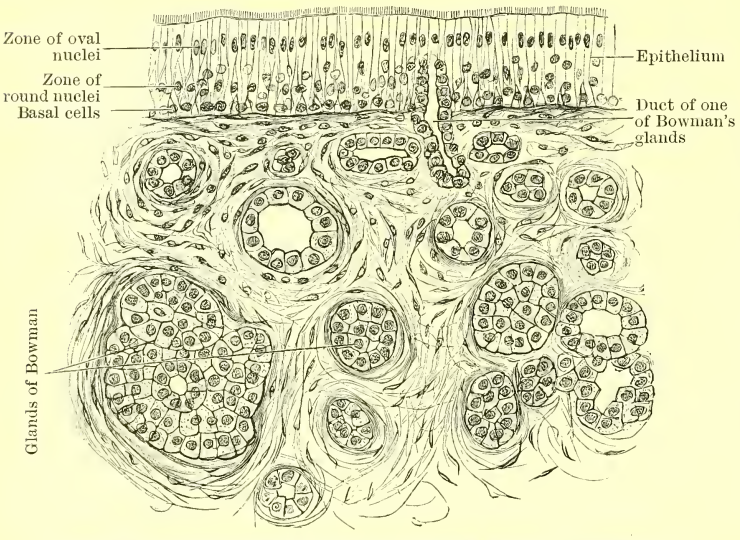


Fig. 556.—Section through the Olfactory Mucous Membrane.

Throughout the respiratory region it is covered by columnar, ciliated epithelium, interspersed amongst which are goblet or mucin cells, whilst between the bases of the columnar cells smaller pyramidal cells are interpolated. It contains a freely anastomosing venous plexus, which in some parts, *e.g.* over the inferior turbinated bones, forms a kind of cavernous tissue (plexus cavernosus concharum). Many acinous glands, secreting a watery fluid, are embedded in it, and are especially large and numerous in the posterior half of the nasal fossæ, while in children it contains a considerable amount of adenoid tissue.

In the olfactory region the mucous membrane is yellowish in colour, more delicate, and covered by non-ciliated columnar epithelium (Figs. 556, 557). Embedded in it are numerous tubular and often branched glands, the **glands of Bowman** (gl. olfactoriæ); these are lined by polygonal cells and open by fine ducts on its free surface. The epithelium covering the olfactory region consists of: (1) supporting cells, (2) olfactory cells, and (3) basal cells.

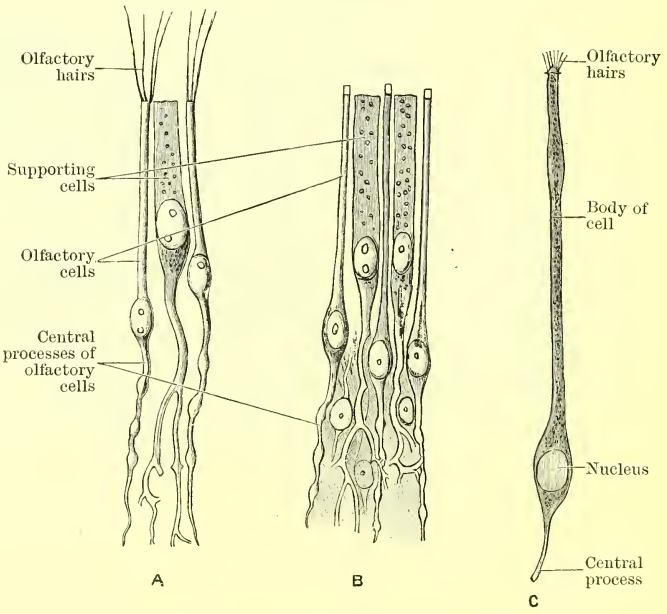


Fig. 557.—Olfactory and supporting Cells.

A. Frog, B. Human } M. Schultze C. Human (v. Brunn).

1. **Supporting Cells.**—The outer part of these cells is columnar in shape and contains fine granules of yellow pigment, whilst the deeper portion is attenuated and frequently branched. They contain elliptical or oval nuclei, which are situated

at the deep ends of the columnar parts of the cells, and form what is termed the zone of oval nuclei.

2. **Olfactory Cells.**—They are spindle-shaped and lie between the deeper, attenuated parts of the supporting cells; their nuclei are circular and form the zone of round nuclei. Each cell gives off a peripheral and a central process, the former of which is rod-like and ends on a level with the free extremities of the supporting cells, where it is surmounted by a pencil of short filaments, termed the **olfactory hairs.** A fine membrane, the membrana limitans externa, covers in many animals the free surface of the epithelium, and is pierced by the olfactory hairs and by the ducts of Bowman's glands.

The central process is a very delicate varicose filament, which passes inwards and is continuous with a fibril of the olfactory nerve. Each of these nerve fibrils probably retains its independence from its point of origin in an olfactory cell to its termination in the olfactory bulb, in the glomerular layer of which it forms a free arborisation.

3. **Basal Cells.**—These cells are branched, and lie on a basement membrane between the deep extremities of the supporting and olfactory cells.

Olfactory Nerves.—These nerves arise from the under aspect of the olfactory bulb and are transmitted through the foramina in the cribriform plate of the ethmoid bone. They are at first lodged in the bony canals or grooves situated on the inner and outer walls of the olfactory area, and, reaching the deep surface of the mucous membrane, are continued into the central processes of the olfactory cells. The olfactory nerves possess no medullary sheath.

The fifth cranial nerve supplies branches of ordinary sensation to the nasal mucous membrane as follows: The septum is chiefly supplied by the naso-palatine nerve, but its posterior part receives some filaments from Meckel's ganglion and the Vidian nerve, and its anterior portion from the nasal branch of the ophthalmic. The outer wall is supplied—(1) by the upper nasal branches of the Vidian nerve and Meckel's ganglion; (2) by the lower nasal branches derived from the anterior palatine; and in front by (3) the outer division of the nasal branch of the ophthalmic. The floor and anterior part of the inferior meatus are supplied by a nasal branch of the anterior superior dental nerve.

Blood-vessels.—Arteries.—The chief artery of the nose is the spheno-palatine branch of the internal maxillary artery. This reaches the nasal cavity through the spheno-palatine foramen, and divides into—(*a*) posterior nasal, which ramifies over the turbinated bones and sends branches to the antrum and to the frontal and ethmoidal cells; and (*b*) naso-palatine, the artery of the septum. Twigs are given to the upper portion of the cavity by the anterior and posterior ethmoidal arteries, while its posterior part receives some small branches from the descending palatine vessel. The nostrils are supplied by the lateral nasal branch of the facial, and by the septal artery of the superior coronary. The antrum is partly supplied by the infraorbital artery, whilst the sphenoidal sinus gets its chief supply from the pterygo-palatine vessel. The **veins** form a dense plexus almost resembling cavernous tissue in structure. This condition is well seen in the respiratory region, and especially so over the middle and inferior turbinated bones and on the lower part of the septum. The venous blood is carried in three chief directions, viz. *forwards* into the facial vein, *backwards* into the spheno-palatine vein, and *upwards* into the ethmoidal veins. The ethmoidal veins communicate with the ophthalmic veins and the veins of the dura mater; further, an ethmoidal vein passes up through the cribriform plate of the ethmoid, and either opens into the venous plexus of the olfactory bulb or directly into one of the veins of the orbital part of the frontal lobe of the brain. The **lymphatics** form an irregular network in the superficial part of the mucous membrane, and can be injected from the subdural or subarachnoid space. The larger vessels are directed backwards towards the choanæ, and are collected into two trunks, of which the larger passes to a lymphatic gland in front of the axis vertebra, and the smaller to one or two glands situated near the great cornu of the hyoid bone.

The development of the nose is described in the section which deals with "General Embryology" (p. 38).

THE EYE.

The eyeball or globe of the eye (bulbus oculi) constitutes the chief part of the organ of sight (organon visus); but, associated with its description, certain accessory structures, such as the eyelids and the lachrymal apparatus, fall to be considered.

THE EYEBALL.

Situated in the anterior part of the orbital cavity, the eyeball is protected in front by the eyelids and by their mucous lining, the conjunctiva, and is pierced behind by the optic nerve, or nerve of sight, which spreads out to form its innermost tunic, the retina. The tendons of the ocular muscles are attached to its outer surface a short distance in front of its equator, while its posterior two-thirds are

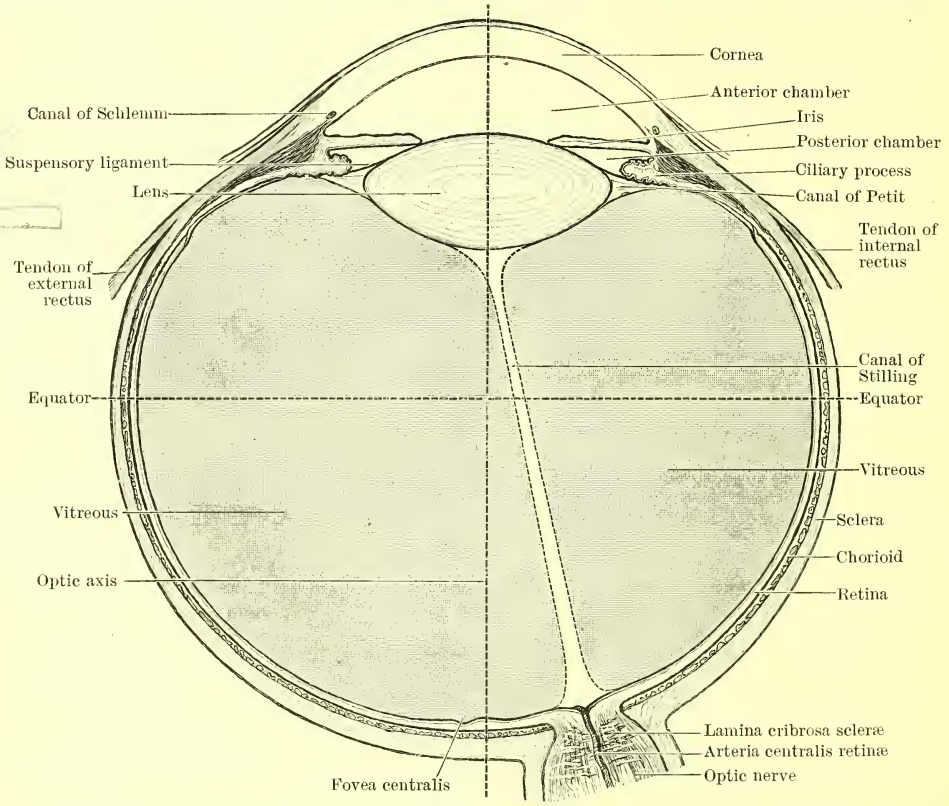


FIG. 558.—DIAGRAM OF A HORIZONTAL SECTION THROUGH LEFT EYEBALL AND OPTIC NERVE (four times enlarged).

enveloped by a loose membrane, termed the capsule of Tenon, or fascia bulbi, which separates it from the surrounding orbital fat.

The eyeball is not quite spherical, being composed of the segments of two spheres, viz. an anterior, transparent, corneal segment, possessing a radius of 7 or 8 mm., and a posterior, opaque, scleral segment, with a radius of about 12 mm. (Fig. 558). The anterior or corneal segment, in consequence of its shorter radius, projects as a dome in front of the scleral portion, the union of the two parts being indicated externally by a slight groove, the sulcus scleræ. The central points of the anterior and posterior curvatures of the eyeball constitute respectively its **anterior** and **posterior poles**, while a straight line joining the two poles is termed its **sagittal axis** (axis optica). The axes of the two eyeballs are almost parallel, diverging only slightly in front; but the axes of the optic nerves converge behind, and, if prolonged backwards, would meet in the region of the dorsum sellæ of the sphenoid. An imaginary line encircling the globe midway between its two poles is named its **equator**, and **meridional lines** (meridiani) may be drawn from pole to pole at right angles to the equator. Its sagittal and transverse diameters are nearly equal—about 24 mm.; its vertical diameter is about 23·5 mm. All three diameters are rather less in the female than in the male, but the size of the eyeball is fairly constant in the same sex. What are popularly described as large eyes owe their apparent increase in size to a greater prominence of the globe and to a wider fissure between the eyelids.

At birth the eyeball is nearly spherical and has a diameter of about 17·5 mm. By the age of puberty this has increased to 20 or 21 mm., after which it rapidly reaches its adult size.

The eyeball (Fig. 558) consists of three concentric tunics or coats, contained within which are three transparent refracting media. The three tunics are: (1) an outer fibrous coat, the sclero-cornea, consisting of an opaque posterior part, the **sclera**, and a transparent anterior portion, the **cornea**; (2) an intermediate vascular, pigmented, and partly muscular tunic, the tunica vasculosa oculi, comprising from behind forward the **chorioid**, the **ciliary body**, and the **iris**; (3) an internal nervous tunic, the **retina**. The three refracting media are named, from before backwards, the **aqueous humour**, the **crystalline lens**, and the **vitreous body**.

SCLERA.

The **sclera**, sclerotic coat, or white of the eye, is a firm, opaque membrane, which forms something like the posterior five-sixths of the outer tunic. Thickest posteriorly (about 1 mm.), it thins at the equator to 0·4 mm.-0·5 mm., and again increases to 0·6 mm. near the sulcus scleræ. In the child it is thinner than in the adult, and presents a bluish appearance, caused by the pigment of the chorioid shining through it, while in old age it assumes a yellowish tinge. Its outer surface is covered by a layer of endothelium and is in contact with the capsule of Tenon—a lymph space, **the suprascleral lymphatic space**, only intervening. In front of the equator it is roughened by the attachment of the tendons of the ocular muscles, while its anterior part is covered by mucous membrane, the conjunctiva. Its deep surface presents a brownish colour, and is loosely attached to the chorioid, except at the optic entrance and in the neighbourhood of the sulcus scleræ. It is pierced behind by the optic nerve, the entrance for which is funnel-shaped, wide behind and narrow in front, and is situated 1 mm. below and 3 mm. to the nasal side of the posterior pole of the eyeball. The fibrous sheath of the nerve blends with the outer part of the sclera, while the nerve bundles pass through a series of orifices; this perforated portion is named the **lamina cribrosa scleræ**. Around the entrance of the optic nerve are some fifteen or twenty small apertures for the passage of the ciliary nerves and short ciliary arteries. The two long posterior ciliary arteries pierce it, one on either side, some little distance from the optic entrance; while a little behind the equator are four openings, two above and two below, for the exit of veins, called **venæ vorticosæ**. Near the sulcus scleræ it is perforated by the anterior ciliary arteries. Its inner surface is lined by flattened endothelial cells; and between it and the chorioid is an extensive lymph space, the **spatium perichorioideale**, which is traversed by the ciliary nerves and arteries just mentioned, and by an irregular meshwork of fine, pigmented, connective tissue, the **lamina fusca**, which loosely attaches the sclera to the chorioid. At the corneo-scleral junction the fibrous tissue of the sclera passes continuously into that of the cornea, and in the deeper part of this junction there is a circular canal, the sinus venosus scleræ, or **canal of Schlemm**, which communicates externally with the scleral veins, and internally, through numerous small openings, with the anterior chamber of the eyeball.

The sclera consists of bundles of white fibrous tissue, together with some fine elastic fibres, the bundles forming equatorial and meridional layers, which interlace with each other. Numerous spaces containing connective tissue cells and migratory cells exist between the fibres. Pigmented cells are plentiful in the lamina fusca, and a few are also found in the tissue of the sclera, near the optic entrance and in the region of the corneo-scleral junction. The sclera receives its blood-supply from the short posterior ciliary and anterior ciliary arteries, while its veins open into the venæ vorticosæ and anterior ciliary veins. The cell spaces play the part of lymphatics, and communicate with the perichorioidal and suprascleral lymph spaces. Its nerves are derived from the ciliary nerves, which, after losing their medullary sheath, pass between the fibrous bundles; their exact mode of ending is not accurately known.

CORNEA.

The **cornea** forms the anterior sixth of the outer tunic and is transparent, in order to admit light into the interior of the eyeball; its index of refraction is from 1·33 to 1·35. Its anterior surface (facies anterior) is covered by a stratified epithelium, continuous with that which lines the conjunctiva; its posterior surface (facies posterior) is directed towards the anterior chamber of the eyeball and is in contact with the aqueous humour. Its degree of curvature varies in different individuals; it is always greater in youth than in old age, and is, as a rule, slightly greater in the vertical than in the horizontal plane. It diminishes also from its centre to its periphery, and is less on the nasal than on the temporal side of the anterior pole. The anterior surface of the cornea is almost, but not quite, circular, measuring 11 mm. vertically and 11·9 mm. transversely, while its posterior surface is circular and has a diameter of 13 mm. Its periphery is overlapped by the tissue of the sclera as the glass of a watch is overlapped by the metal rim, with, however, this essential difference, that the tissue of the cornea is directly continuous with that of the sclera.

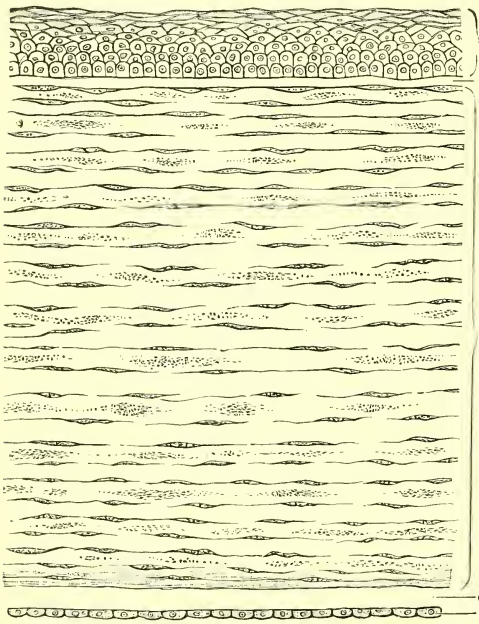


Fig. 559.—Vertical Section of Cornea (magnified).

The cornea consists, from before backwards, of the following strata, viz, (Fig. 559):—

1. A layer of stratified epithelium.
2. An anterior elastic lamina.
3. The substantia propria.
4. A posterior elastic lamina.
5. A layer of endothelium.

1. The **layer of stratified epithelium** (epithelium corneæ) is continuous with that which covers the free surface of the conjunctiva and consists of six or eight strata of nucleated cells. Deepest of all is a single layer of perpendicularly arranged columnar cells, the flattened and often-expanded bases of which rest on the anterior elastic lamina, while their opposite ends are rounded and contain the nuclei. Superficial to this layer are three or four strata of nucleated, polygonal cells, the majority of which exhibit finger-like processes which join with the corresponding processes of neighbouring cells. The more superficial layers assume the form of nucleated squames. The entire thickness of this stratified epithelium is about 45 μ at the centre and about 80 μ at the periphery of the cornea.

2. The **anterior elastic lamina** (lamina elastica anterior, Bowmani) is from 19-20 μ thick, and may be regarded merely as a differentiation of the outer part of the substantia propria from which it is with difficulty separated. It is not stained yellow by picrocarmine, thus differing from true elastic tissue, and its degree of development varies in different animals.

3. The **substantia propria** presents, in a fresh condition, a homogeneous appearance; but, with the assistance of reagents, it is seen to consist of modified connective tissue, with some few elastic fibres. An amorphous interstitial substance binds the fibres into bundles, and, in turn, cements the bundles into lamellæ, which are directly continuous with the fibrous tissue of the sclera. The fibres of any one lamella cross those of adjacent lamellæ almost at right angles, while the superimposed lamellæ are joined by sutural fibres and by amorphous substance. Between the lamellæ are found the **cell spaces** or **lacunæ** of the cornea—irregu-

larly stellate in shape, and communicating freely with each other by means of fine canaliculi. The corneal cells or corpuscles are contained in these lacunæ, without, however, completely filling them, the remainder of the cavities being occupied by lymph. These cells are nucleated, flattened, and star-like, and their branched processes join those of neighbouring cells in the canaliculi. Migratory or lymph cells are also found in cell spaces.

In old age a grayish opaque ring, 1½ to 2 mm. in breadth, is frequently seen near the periphery of the cornea; it is termed the **arcus senilis**, and results from a deposit of fat granules in the lamellæ and corneal corpuscles.

4. The **posterior elastic lamina** (lamina elastica posterior, Demoursi, Descemeti) is a clear, structureless membrane, covering the posterior aspect of the substantia propria and possessing a thickness of 6-8 μ at the centre and 10-12 μ at the periphery of the cornea. Less firmly attached than the anterior elastic lamina, it may be stripped off, when it will be found to roll up with its attached surface inwards. Between the ages of twenty and thirty small wart-like projections appear on its deep surface, near its periphery, and these increase in size and number as years advance, so that in old age the membrane may attain a thickness of 20 μ. Towards the periphery of the cornea the lamina divides into three sets of fibres—anterior, middle, and posterior. The anterior fibres pass behind the canal of Schlemm into the sclera, the middle give attachment to the ciliary muscle, while the posterior are continued as radiating and anastomosing fibres into the substance of the iris, and constitute the **ligamentum pectinatum iridis.** A number of irregular spaces, the **spaces of Fontana**, or spatia anguli iridis, exist between the fibres of this pectinate ligament. Better developed in the horse and ox than in man, these spaces are lined by a prolongation of the corneal endothelium, and communicate internally with the anterior chamber and the lymph spaces of the iris, and externally with the canal of Schlemm.

5. The **layer of endothelium** (endothelium cameræ anterioris) consists of a single stratum of nucleated, flattened, polygonal cells, which present a fibrillar structure and are continued as a lining to the spaces of Fontana; this layer of endothelium is also reflected on to the anterior surface of the iris.

Vascular and Nervous Supply of the Cornea.—In the fœtus the cornea is traversed, almost as far as its centre, by capillaries; but in the adult it is devoid of blood-vessels, except near its margin. The capillaries of the conjunctiva and sclera pass into this marginal area for a distance of about 1 mm., where they terminate in loops. All the remainder of the cornea is nourished by the lymph which circulates in its cell spaces and canaliculi.

The **nerves** of the cornea, discovered by Schlemm, are derived from the ciliary nerves. Around its periphery they form a plexus, the plexus annularis, from which fibres pass into the cornea, where, after a distance of 1 or 2 mm., they lose their medullary sheaths and ramify in the substantia propria, forming what is termed the fundamental or stroma plexus. Perforating fibres (fibræ perforantes) extend from this plexus through the anterior elastic lamina and form a subepithelial plexus, from which fine filaments ramify between the epithelial cells as far as the superficial layers. From the annular and stroma plexuses fibrils pass to the substantia propria and come into close relation with the corneal corpuscles.

VASCULAR AND PIGMENTED TUNIC.

The middle, vascular, and pigmented tunic (tunica vasculosa oculi) comprises, from behind forwards, the chorioid, the ciliary body, and the iris (Fig. 558).

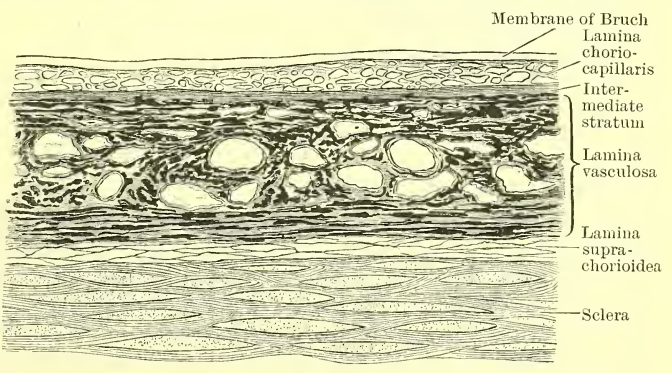


Fig. 560.—Vertical Section of Chorioid and Inner Part of Sclera.

The **chorioid** (chorioidea) intervenes between the sclera and the retina, reaching as far forwards as the ora serrata of the latter (p. 731). Dark brown or black in colour, it is pierced posteriorly by the optic nerve, and is here firmly attached

to the sclera. Thicker behind than in front, its outer surface is flocculent and is connected to the sclera by the ciliary vessels and nerves, and by the loose lamina fusca. Its inner surface is smooth and adheres to the outermost or pigmented layer of the retina.

The chorioid consists of blood-vessels and branched pigment cells embedded in a loose connective tissue, and presents from without inwards three layers, viz.: (*a*) the lamina suprachorioidea; (*b*) the proper tissue of the chorioid; and (*c*) a thin transparent membrane, the lamina basalis or membrane of Bruch (Fig. 560).

1. The **lamina supra-chorioidea** resembles the lamina fusca of the sclera, and consists of a series of fine non-vascular lamellæ, each containing a delicate network of elastic fibres, amongst which are stellate, pigmented cells, together with amœboid cells. The spaces between the laminæ are lined with endothelium, and together form the spatium perichorioideale, already referred to (p. 725).

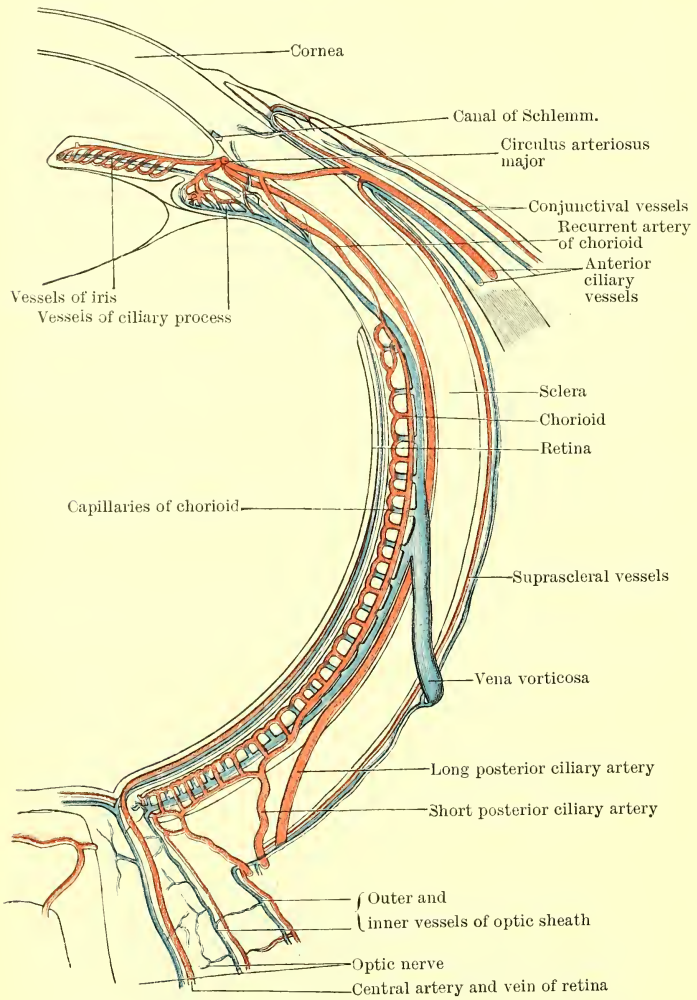


FIG. 561.—DIAGRAM OF THE CIRCULATION IN THE EYE (Leber).

The **proper tissue of the chorioid** consists of blood-vessels and numerous pigmented cells, supported by connective tissue and elastic fibres, together with some smooth muscular fibres. Its outer part contains the larger blood-vessels, and is named the **lamina vasculosa**, while its inner portion is composed of a network of fine capillaries, and is termed the **lamina choriocapillaris**; these two laminæ are joined by a thin **intermediate stratum.** The arteries of the chorioid are derived from the short posterior ciliary vessels, which pierce the sclera around the optic entrance and form a wide-meshed plexus in the lamina vasculosa. Their circular muscular coat is well developed, and longitudinal muscular fibres are also present in the larger branches. The veins, destitute of muscular tissue, are superficial to the arteries; they are surrounded by peri-vascular lymphatic sheaths and converge to form whorls, which open into the venæ vorticosæ. In the tissue between the blood-vessels are numerous stellate, flattened, and pigmented cells.

The **lamina chorio-capillaris**, or membrane of Ruysch, is composed essentially of small capillaries, which form an exceedingly close network, embedded in a finely granular or almost homogeneous tissue. The **intermediate stratum** between the malina vasculosa and lamina chorio-capillaris consists of a network of delicate

elastic fibres and contains almost no pigment cells; it is lined next the lamina chorio-capillaris by a continuous layer of endothelium.

The **lamina basalis**, or membrane of Bruch, is transparent and nearly structureless. Its outer surface presents a trellis-like network of fibres which unite it to the membrane of Ruysch, while its inner surface is smooth and is in contact with the pigmented layer of the retina.

Tapetum.—In many animals a brilliant iridescent appearance is seen on the postero-external part of the chorioid to which the name **tapetum** is applied. Absent in man, it may be due, as in the horse, to a markedly fibrous condition of the stratum intermedium (tapetum fibrosum), or as in the seal, to the presence of some five or six layers of flattened iridescent cells lying immediately outside the lamina chorio-capillaris (tapetum cellulosum).

The **ciliary body** (corpus ciliare) connects the chorioid to the circumference of the iris (Fig. 562), and presents the following three zones, viz.: (*a*) the orbiculus ciliaris, (*b*) the ciliary processes, and (*c*) the ciliary muscle.

The **orbiculus ciliaris** forms a zone of about 4 mm. in width immediately adjoining the chorioid, and exhibits numerous radially-arranged ridges.

The **ciliary processes** (processus ciliares), about seventy in number, form a circle of radial thickenings, each of a somewhat triangular shape. The base of the triangle is directed forwards towards the equator of the lens, while the apex is continuous behind with some three or four ridges of the orbiculus ciliaris. They vary in size, the largest having a length of 2-5 mm. The structure of the orbiculus ciliaris and ciliary processes is similar to that of the chorioid, but the capillaries are larger and more tortuous, and there is no lamina chorio-capillaris. The deep aspect of the ciliary processes is covered by two strata of columnar epithelium, the anterior layer of which is pigmented; these two strata form a direct continuation forwards of the retina and constitute the **pars ciliaris retinæ**. This epithelium is invaginated to form more or less tubular glands, which may take a share in the secretion of the aqueous humour.

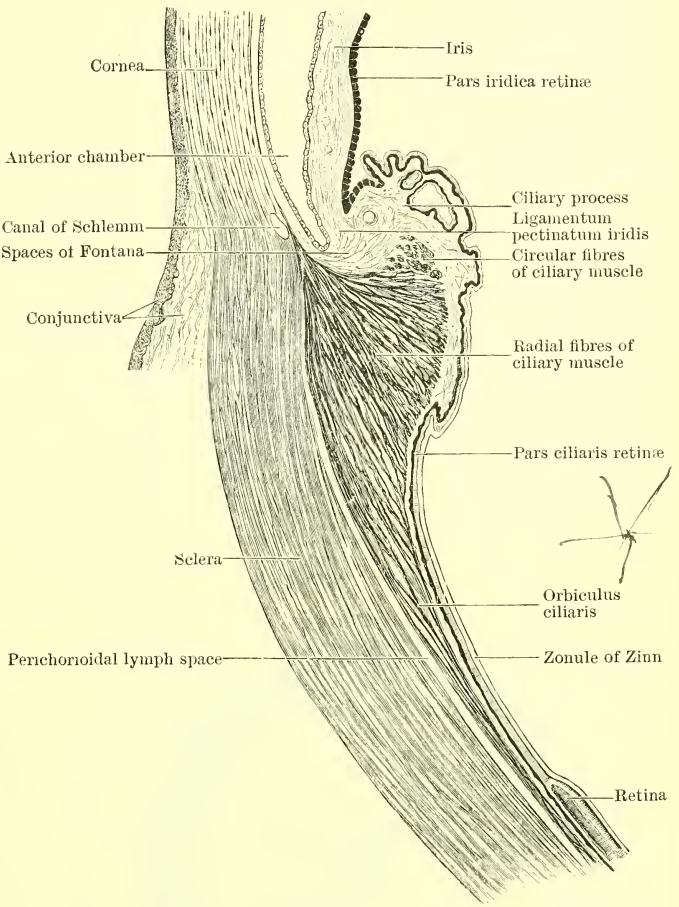


Fig. 562.—Section through Ciliary Region of Eyeball.

The **ciliary muscle** (m. ciliaris) is triangular on antero-posterior section, and consists of two sets of fibres—radial and circular (Fig. 562). The **radial fibres** (fibræ meridionales, Brückei) spring from the corneo-scleral junction behind the canal of Schlemm and from the ligamentum pectinatum iridis, and radiate backwards, to be attached to the ciliary processes and orbiculus ciliaris. When they contract the chorioid is drawn forwards and the lens becomes more convex, owing to the relaxation of its suspensory ligament (see p. 736). The **circular fibres** (fibræ

circulares, Mülleri) form a triangular zone behind the ligamentum pectinatum iridis, close to the periphery of the iris, and also extend backwards under the radial fibres. Considerable individual differences are found as to the degree of development of these two portions of the ciliary muscle. The radial fibres are always more numerous than the circular fibres, the latter being absent or rudimentary in myopic eyes, but well developed, as a rule, in hypermetropic eyes.

The **iris** forms a contractile diaphragm in front of the lens, and is pierced a little to the nasal side of its centre by an almost circular aperture, the **pupil** (pupilla), which, during life, is continually varying in size in order to regulate the amount of light admitted into the interior of the globe. It divides the space between the cornea and lens into two parts, which are filled by the aqueous humour, and named respectively the **anterior and posterior chambers** of the eyeball. Its peripheral border, or **margo ciliaris**, is directly continuous with the ciliary body, and, through the medium of the ligamentum pectinatum iridis, with the posterior elastic lamina of the cornea. Its free edge, or **margo pupillaris**, forms the circumference of the pupil, and rests upon, but is not attached to the anterior surface of the capsule of the lens.

The distinctive colour of the eye, in different individuals, depends on the arrangement of the pigment in the iris; in the blue eye this is limited to the posterior surface of the iris, but in the brown or black eye it is also scattered throughout its stroma. In the albino the pigment is entirely absent, and the red appearance of the eye in such a case is produced by the network of blood-vessels in the iris.

The pupil is closed, during the greater part of fœtal life, by a thin transparent vascular membrane, the **membrana pupillaris**, continuous with the pupillary margin of the iris. Its vessels, derived partly from the vessels of the iris and partly from those of the capsule of the lens, converge towards the middle of the membrane, near which they form loops so as to leave the central part non-vascular. About the seventh month the vessels begin to be obliterated from the centre towards the circumference, and this is followed by a thinning and absorption of the membrane, which becomes perforated by the aperture of the pupil. This perforation gradually enlarges, and at birth the membrane has entirely disappeared, although in exceptional cases it persists.

On the anterior surface (facies anterior) of the iris is a layer of flattened endothelium, placed on a basement membrane, and continuous with that which lines the spaces of Fontana and covers the back of the cornea. Depressions or crypts are here and there seen in which the endothelium and basement membrane are absent, and are, by some, regarded as stomata, through which the lymphatics of the iris communicate with the cavity of the anterior chamber. Its posterior surface (facies posterior) is covered by a basement membrane, on which are placed two layers of columnar, pigmented epithelium, continuous with the pars ciliaris retinæ and termed the **pars iridica retinæ.** The proper tissue of the iris, or **stroma iridis**, consists of delicate connective tissue and elastic fibres, with pigmented cells, blood-vessels, nerves, and non-striped muscle.

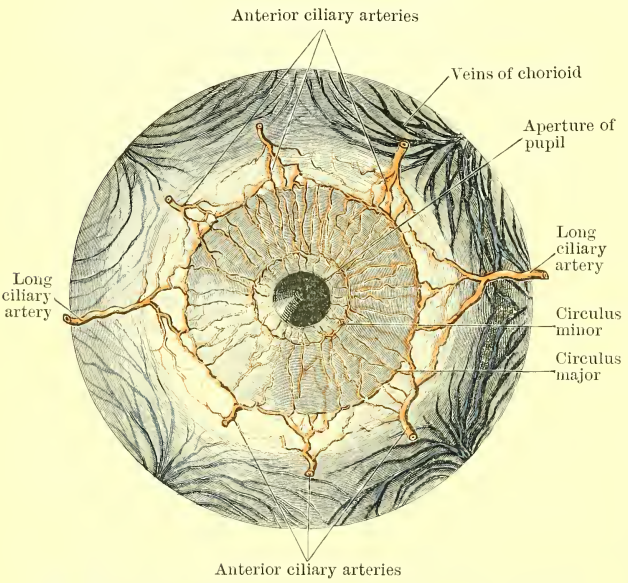


FIG. 563.—BLOOD-VESSELS OF IRIS AND ANTERIOR PART OF CHORIOID, viewed from the front (Arnold).

The **blood-vessels of the iris** (Fig. 563) are derived from the long and anterior

ciliary arteries. The long ciliary arteries, two in number, pierce the sclera on the inner and outer side of the optic nerve respectively, and extend forwards between the sclera and chorioid towards the ciliary margin of the iris. Here each divides into an upper and a lower branch, and the resulting four branches anastomose in the form of a circle, termed the **circulus arteriosus major**. This circle is joined by a varying number of anterior ciliary arteries derived from the lachrymal and muscular branches of the ophthalmic artery, and, after supplying the ciliary muscle, sends converging branches inwards towards the aperture of the pupil, around which a second circle, the **circulus arteriosus minor**, is formed. The **veins** proceed towards its ciliary margin, and communicate with the veins of the ciliary processes and with the canal of Schlemm. The convergence of the blood-vessels towards the aperture of the pupil gives to the anterior surface of the iris a striated appearance.

The **non-striped muscular fibres** are arranged in two sets: (*a*) circular, (*b*) radial. The **circular fibres** form a band around the pupillary aperture, by the contraction of which its size is lessened, and hence it is termed the **m. sphincter pupillæ**. The **radial fibres** extend outwards from the sphincter to the ciliary margin and constitute the **m. dilatator pupillæ**. Many anatomists regard the radial fibres, in man and most mammals, as being elastic and not muscular. In animals, where the radial fibres are muscular, the degree of their development varies considerably; they are feebly marked in the rabbit, but well developed in the bird, and still more so in the otter.

The **nerves of the chorioid and iris** are derived from the long and short ciliary nerves. The former, two or three in number, are branches of the nasal nerve; the latter, varying from eight to fourteen, are derived from the ciliary ganglion. Piercing the sclera around the optic entrance the nerves traverse the perichorioidal lymph space, where they form a plexus, rich in nerve-cells, from which filaments are supplied to the blood-vessels of the chorioid. In front of the ciliary muscle a second plexus, also rich in nerve-cells, is formed, which supplies the muscle itself, and sends filaments into the iris as far as its pupillary margin, for the supply of its muscular fibres and blood-vessels. The sphincter pupillæ is supplied by the third cranial nerve, whilst filaments from the sympathetic are distributed to the dilatator pupillæ.

THE RETINA.

The **retina**, or nervous tunic of the eyeball, is a soft, delicate membrane, in which the fibres of the optic nerve are spread out. It consists of two strata, viz.: (*a*) an outer, pigmented layer (stratum pigmenti), attached to the chorioid; and (*b*) an inner nervous lamina, the retina proper, in contact with the hyaloid membrane of the vitreous body, but only attached to it at the optic entrance and in the region of the ciliary processes. Expanding from the entrance of the optic nerve the retina appears to end, a short distance behind the ciliary body, in a wavy border, the **ora serrata**. Here its nervous elements cease and the membrane becomes suddenly thinned, but a delicate continuation of it is prolonged over the posterior aspect of the ciliary body and iris. This continuation consists of the stratum pigmenti, together with a layer of columnar epithelium, and constitutes the **pars ciliaris retinæ** and **pars iridica retinæ** already referred to (pp. 729 and 730). The portion behind the ora serrata is termed the "physiological retina," or **pars optica retinæ**, and its thickness gradually diminishes from 0·4 mm., near the optic entrance, to 0·1 mm. at the ora serrata. Viewed from the front it presents, at the posterior pole of the eyeball, and therefore directly in the axis of the globe, a small yellowish spot, the **macula lutea**. Somewhat oval in shape, the greatest or transverse diameter of the macula measures from 2-3 mm.; its central part is depressed and named the **fovea centralis**. About 3 mm. to the nasal side of the posterior pole and about 1 mm. below its level is a whitish, circular disc, the **optic disc**, or porus opticus, which corresponds with the entrance of the optic nerve and has a diameter of about 1·5 mm. The circumference of the optic disc is slightly raised and is named the **colliculus nervi optici**, while its depressed central portion is termed the **optic cup**, or excavatio papillæ nervi optici. The optic disc consists merely of nerve-

fibres, the other layers of the retina being absent, and constitutes the "blind spot" of physiologists.

The nervous layer of the retina is transparent during life, but becomes opaque and of a grayish colour soon after death. If an animal be kept in the dark before the removal of its eyeball, the retina presents a purple tinge, due to the presence of a colouring matter named **rhodopsin** or **visual purple**, which, however, becomes rapidly bleached on exposure to sunlight. This colouring matter is absent from the macula lutea, and also over a narrow zone, 3-4 mm. in width, near the ora serrata.

Structure of the Retina (Figs. 564, 565, 566).—The nervous elements of the retina are supported by non-nervous or **sustentacular fibres**, and are arranged in seven layers, to which must be added the stratum pigmenti.

Our conception of the minute structure of the retina, as of all nervous tissues, has of late years been greatly advanced by the discoveries of Ramon y Cajal, on whose observations the following description is based (Fig. 565):—

The layers from within outwards, *i.e.* from vitreous body to chorioid, are:

1. Layer of nerve-fibres (stratum opticum).
2. Layer of nerve-cells (ganglionic layer).
3. Inner molecular or inner plexiform layer.
4. Inner nuclear layer or layer of inner granules.
5. Outer molecular or outer plexiform layer.
6. Outer nuclear layer or layer of outer granules.
7. Layer of rods and cones (bacillary layer).
8. Layer of pigmented epithelium (stratum pigmenti).

1. **Layer of nerve-fibres or stratum opticum.**—The fibres of this stratum are nearly all centripetal, and are mostly continuations of the non-medullated axons of the cells in the ganglionic layer. Some, however, are centrifugal and end in branched clubbed extremities in the inner molecular or inner nuclear layers.

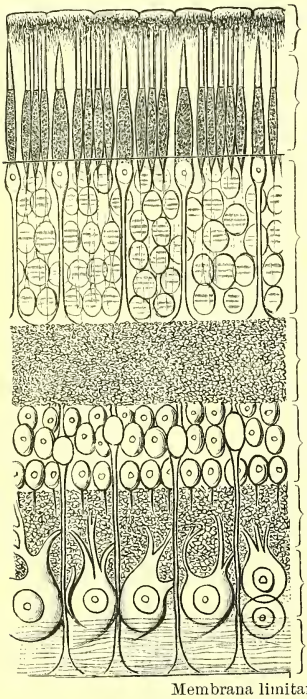


FIG. 564.—DIAGRAMMATIC SECTION OF THE HUMAN RETINA (modified from Schultze).

2. **Ganglionic or nerve-cell layer.**—The cells of this stratum vary in size, are oval or pyriform in shape, and form a single layer, except at the macula lutea, where several strata are present. Each cell contains a large nucleus, and gives off, from its inner aspect, an axon which is continued as a fibre of the nerve-fibre layer. From the outer surface of each cell numerous dendrites arise, which form arborisations in the inner molecular layer. The cells may be divided into unistratified, multistratified, and diffuse, according as their dendrites ramify in one or in several strata of the inner molecular layer, or extend throughout nearly its whole thickness.

3. **Inner molecular or inner plexiform layer.**—This is chiefly constituted by the interlacement of the dendritic arborisations of the cells of the ganglionic layer with those of the inner nuclear layer, and has been divided by Ramon y Cajal into five strata. It sometimes contains horizontal cells or spongioblasts, whose branched processes ramify in it.

4. **Inner nuclear layer or layer of inner granules.**—This is the most complicated of the retinal strata, and consists of numerous cells which may be divided into three groups, viz.: (*a*) bipolar cells, (*b*) horizontal cells, and (*c*) spongioblasts, or amacrine cells.

(*a*) The **bipolar cells**, by far the most numerous are fusiform and nucleated, and each gives off an external and an internal process. The internal processes terminate in flattened tufts at different levels in the inner molecular layer, while the external produce an abundant ramification in the external zone of the outer molecular layer. These bipolar cells are divided into rod bipolars, cone bipolars, and giant bipolars. The **rod bipolars** end peripherally in vertical arborisations around the button-like ends or spherules of the rod fibres, and, centrally, in branched extremities

which mostly become applied to the cells of the ganglionic layer. The **cone bipolars** end peripherally in flattened arborisations in the outer molecular layer in contact with

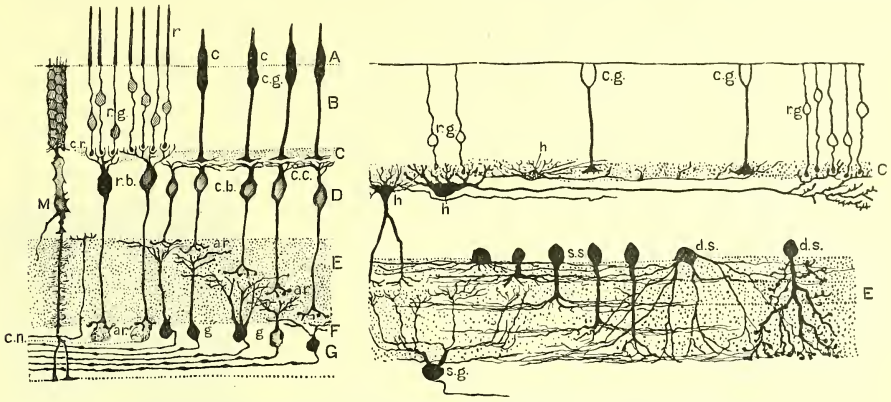


Fig. 565.—Perpendicular Sections of Mammalian Retina (Cajal).

A, Layer of rods and cones; B, Outer nuclear layer; C, Outer molecular layer; D, Inner nuclear layer; E, Inner molecular layer; F, Ganglionic layer; G, Stratum opticum; *r*, rods; *c*, cones, *r.g*, rod granules; *c.g*, cone granules; *r.b*, rod bipolars; *c.b*, cone bipolars; *c.r*, contact of rod bipolars with the spherules of the rod fibres; *c.c*, contact of cone bipolars with the branches of the cone fibres; *ar*, internal arborisation of cone bipolars; *ar'*, internal arborisation of rod bipolars; *c.n*, centrifugal nerve fibre; *h*, horizontal cells; *s.s*, stratified spongioblasts; *d.s*, diffuse spongioblasts; *s.g*, stratified ganglion cell; M, Sustentacular fibre of Müller.

the ramifications of the foot-plates of the cone fibres, and, centrally, ramify in some one of the five strata of the inner molecular layer. The **giant bipolars** form, peripherally, an extensive horizontally arranged arborisation in the outer molecular layer; centrally, they ramify in one or other of the strata of the inner molecular layer.

(*b*) The **horizontal cells** are of two varieties: (1) small, flattened, star-like cells, lying immediately below the outer molecular layer, and sending a tuft of dendrites outwards towards the bases of the cone fibres, while their axons are directed horizontally for a variable distance; (2) large, irregular cells, lying internal to the above and ending in finger-like ramifications in the outer molecular layer. Their axons run horizontally for some distance, and end in extensive varicose arborisations under the spherules of the rod fibres.

(*c*) The **spongioblasts** are situated in the innermost part of the inner granular layer and have not yet been shown to possess axons. Their dendrites ramify in the inner molecular layer, it may be in one stratum (stratified spongioblasts) or in several strata (diffuse spongioblasts).

5. **Outer molecular or outer plexiform layer.**—This is constituted by the interlacement of the dendrites of the bipolar and horizontal cells, just described, with the spherules of the rod fibres and the ramifications of the foot-plates of the cone fibres. It is divided into two strata: (*a*) *external*, indicating the contact of the rod bipolars with the spherules of the rod fibres; (*b*) *internal*, the line of contact between the cone bipolars and the branches of the cone fibres.

6. **Outer nuclear layer or layer of outer granules.**—This is made up of clear granules somewhat resembling those of the inner nuclear layer, and are divisible into two kinds: (*a*) cone granules, (*b*) rod granules. The **cone granules** are the larger, and each contains an oval nucleus; they lie immediately inside the outer limiting membrane, through which they are continuous with the cones of the next layer. Each is prolonged internally as a straight fibre, which, on reaching the outer molecular layer, expands to form a foot-plate, from which several horizontal fibrils are given off. The **rod granules** are far more numerous than the cone granules, and each contains a small oval nucleus, which is transversely striated.

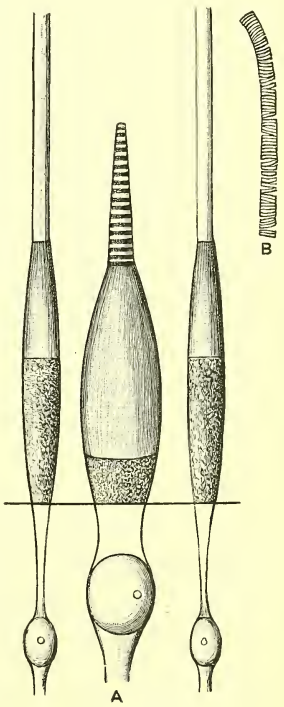


Fig. 566.

A, A cone and two rods from the human retina (modified from Max Schultze); B, Outer part of rod separated into discs.

Their outer processes are continuous, through the outer limiting membrane, with the rods of the next layer, while their inner processes pass into the outer molecular layer and end in free, unbranched spherules amongst the arborisations of the rod bipolars.

7. **Layer of rods and cones.**—This consists of two sets of structures, viz. **rods** and **cones.** Except at the macula lutea the rods are far more numerous than the cones and assume the form of elongated cylinders, while the cones are shorter than the rods and taper externally to fine points. Each rod and cone consists of two segments—inner and outer. The inner segment of the rod only slightly exceeds in diameter its outer segment, whereas the inner segment of the cone greatly exceeds its outer part. The inner segments of both rods and cones have an affinity for staining reagents, and consist of a basal homogeneous portion and an outer longitudinally striated part, the proportion of the latter to the former being greater in the cones than in the rods. The outer segments have not the same affinity for reagents, but tend to break transversely into numerous discs (Fig. 566, B). The colouring matter, rhodopsin, already referred to, is found only in the outer segments of the rods, the terminal parts of which extend into the layer of pigmented epithelium.

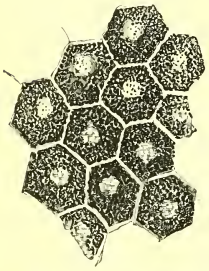


FIG. 567.—PIGMENTED EPITHELIUM OF HUMAN RETINA (viewed from the surface).

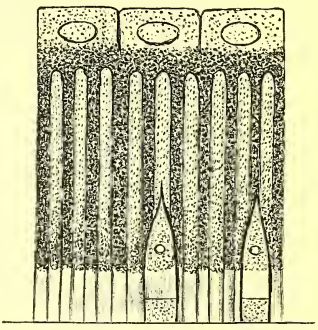


FIG. 568.—SECTION THROUGH OUTER LAYERS OF RETINA (semi-diagrammatic).

8. **Layer of pigmented epithelium** (stratum pigmenti).—This consists of a single stratum of cells which, on surface view, are hexagonal (Fig. 567), their outer flattened surfaces being firmly attached to the chorioid. When seen in profile the outer part of each cell contains a large oval nucleus and is devoid of pigment, while the inner portion is filled with pigment and extends as a series of thread-like processes amongst the outer segments of the rods and cones. When the eye is kept in the dark the pigment accumulates near the outer part of the cell, but when exposed to light it streams in between the rods and cones (Fig. 568).

It will be seen from the foregoing description that there is no direct continuity between the nervous elements which form the different layers of the retina. In the inner molecular layer there is merely an interlacement between the dendrites of the ganglionic layer and the arborisations of the cells of the inner granular layer, and a similar interlacement in the outer molecular layer between the rod and cone elements and the processes of the outer granules.

Sustentacular fibres of the retina (fibræ Mülleri).—These support the nervous structures and extend from within outwards through the thickness of the retina as far as the bases of the rods and cones (Fig. 565, M). They begin at the inner surface of the nerve-fibre layer in single or forked expanded bases, by the apposition of which a delicate membrane, the **membrana limitans interna**, is formed. In the ganglionic layer they give off a few lateral branches, and, on passing through the inner nuclear layer, supply lateral ramifications amongst the inner granules for their support; in this part of each fibre there is seen an oval nucleus. In the outer nuclear layer they break up into a network of fibrils which surround the rod and cone fibres, and end externally at the bases of the rods and cones in a delicate membrane, the **membrana limitans externa.**

Structure of the macula lutea and fovea centralis.—The yellow colour of the macula is due to the presence of pigment in the inner layers of the retina. At the circumference of the macula the nerve-fibre layer is greatly thinned and the rods are few in number; the ganglionic layer, on the other hand, is thickened and may contain from seven to nine strata of cells, while the outer granular layer is also thicker and its bipolar cells have an oblique direction. At the fovea centralis the retina is much thinned, since here its nerve-fibre and ganglionic layers are absent and its other strata greatly attenuated. The stratum pigmenti, on the other hand, is thicker and its pigmentation more pronounced. The cone nuclei are situated some distance internal to the outer limiting membrane, and thus the thin inner and outer granular layers are in apposition. There are no rods, and the cones, closely crowded together, are narrower and their outer segments more elongated than elsewhere, so that the line of their bases, indicated by the membrana limitans externa, presents a convexity directed forwards. The fovea centralis and macula lutea are spoken of by the physiologist as the "region of distinct vision."

Structure of the ora serrata.—Here the nervous layers of the retina suddenly cease; the layer of rods and cones first failing, to be immediately followed by the disappearance of the other nervous strata. In front of the ora serrata the retina is prolonged over the ciliary processes in the form of two layers of cells: (*a*) an inner layer of columnar epithelium, and (*b*) an outer, consisting of the stratum pigmenti, the two forming the pars ciliaris retinæ. The same two layers are prolonged over the back of the iris, where both are pigmented and form the pars iridica retinæ.

Vessels of the retina (Fig. 569).—The retina is supplied by the **arteria centralis retinæ**, a branch of the ophthalmic artery, which pierces the sheath of the optic nerve about three-quarters of an inch behind the eyeball, and makes its appearance in the centre of the optic disc. Here it divides into an upper and a lower branch, and each of these again bifurcates into an internal or nasal, and an external or temporal, branch. The resulting four branches ramify towards the periphery of the retina, and are named the superior and inferior temporal and the superior and inferior nasal arteries. The temporal arteries pass outwards above and below the macula lutea, to which they give small branches;

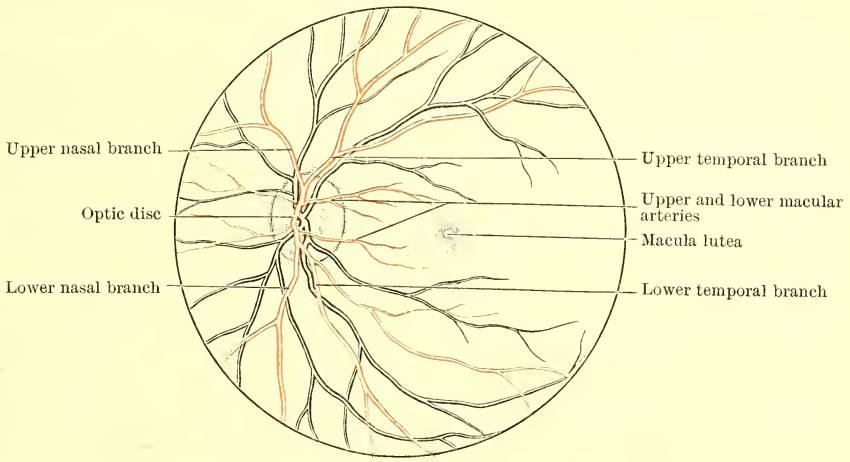


Fig. 569.—Blood-vessels of the Retina.

these do not, however, extend as far as the fovea centralis, which is devoid of blood-vessels. The macula also receives two small arteries (superior and inferior macular) directly from the porus opticus. The larger vessels run in the nerve-fibre layer near the membrana limitans interna and form two capillary networks—an inner, in the nerve-fibre layer, and an outer, in the inner nuclear layer. The inner network arises directly from the arteries and sends numerous small branches to the outer network, from which the veins take origin. The vessels do not penetrate deeper than the inner granular layer, nor do the arteries anastomose except through the capillary plexuses. The **veins** follow the course of the arteries; they have no muscular coats, but consist merely of a layer of endothelial cells, outside which is a perivascular lymphatic sheath, surrounded by delicate retiform tissue.

REFRACTING MEDIA OF THE EYEBALL.

The **vitreous body** (corpus vitreum) is a transparent, jelly-like substance situated between the crystalline lens and the retina, and occupying the posterior four-fifths of the globe (Fig. 558). In front it presents a deep concavity, the **fossa patellaris**, for the reception of the posterior convexity of the lens. It is enclosed within a thin transparent membrane, the **membrana hyaloidea**, which is in contact with the membrana limitans interna of the retina and adherent to it at the optic entrance. The portion of the membrana hyaloidea in front of the ora serrata is thickened and strengthened by radial fibres, and is termed the **zonule of Zinn**, or zonula ciliaris. Situated behind the ciliary body the zonula is radially folded and presents a series of alternating furrows and elevations. The ciliary processes are received into, and are firmly adherent to, the furrows, with the result that, if removed, some of their pigment remains attached to the zonula. The elevations of the zonula are not attached to the interciliary depressions, but are separated by a series of lymph spaces (recessus cameræ posterioris); these may be regarded as diverticula of the

posterior chamber with which they communicate. As the zonula approaches the equator of the lens it splits into two chief layers, viz.: (*a*) a thin posterior lamina, which covers that portion of the membrana hyaloidea which lines the fossa patellaris; and (*b*) a thicker anterior layer, termed the **suspensory ligament** of the lens (Fig. 558), which blends with the front of the lens capsule a short distance from its equator. Scattered fibres of this ligament are also attached to the equator itself and to the regions immediately anterior and posterior to it. By this suspensory ligament the lens is retained in position, and its convexity varies inversely with the degree of tension of the ligament. The radial fibres of the ciliary muscle, by pulling forward the ciliary processes and the attached zonule of Zinn, relax the ligament, and thus allow the lens to become more convex. Behind the suspensory ligament a sacculated lymph space surrounds the equator of the lens; it is named the **canal of Petit**, and may easily be inflated on introducing a fine blow-pipe through the suspensory ligament (Fig. 570). In the fœtus a blood-vessel, termed the **arteria hyaloidea**, is continued from the arteria centralis retinæ forwards through the vitreous body for the supply of the capsule of the lens. Its position, in the adult, is represented by a lymph channel, termed the **canalis hyaloideus** of Stilling (Fig. 558), the presence of which may be demonstrated by shaking up the vitreous body in a solution of picrocarmine, when some of the pigment may be seen to extend along the canal (Anderson Stuart).

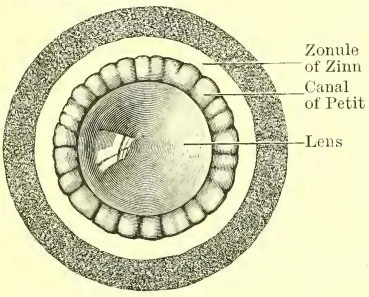


Fig. 570.—Canal of Petit distended and viewed from the Front (enlarged).

When the vitreous body is treated by a weak solution of chromic acid it presents a series of concentric, peripherally arranged striæ, together with numerous radial striæ converging towards its centre. Between these the more fluid part lies, and it frequently contains vacuolated amœboid cells scattered through it. The vitreous body consists of 98·4 per cent of water, having in solution about 1·4 per cent of sodium chloride and traces of extractives and albumen.

The **crystalline lens** (lens crystallina) lies in front of the vitreous body and behind the iris, and is a biconvex, transparent body (Fig. 558). It is enclosed in a thin, transparent, homogeneous capsule, the capsule of the lens (capsula lentis). The central points of its anterior and posterior surfaces are termed respectively its **anterior and posterior poles**, a line joining which is known as its **axis** (axis lentis); its peripheral circumference is named the **equator** (æquator lentis). Its axial measurement is 4 mm., and its transverse diameter from 9-10 mm. Its anterior surface (facies anterior lentis) is less curved than the posterior, and its central part corresponds with the aperture of the pupil and is directed towards the anterior chamber. Around the aperture of the pupil the pupillary margin of the iris rests upon the lens, but its peripheral part is separated from it by the aqueous humour of the posterior chamber. Its posterior surface (facies posterior lentis), more convex than the anterior, occupies the fossa patellaris of the vitreous body. The relations of its equator to the suspensory ligament and the canal of Petit have already been referred to. The superficial part of the lens possesses a refractive index of about 1·4, and its central part or nucleus one of about 1·45. The curvatures of its surfaces, especially that of the anterior, are constantly varying during life for the purpose of focusing rays from near or distant objects on the retina.

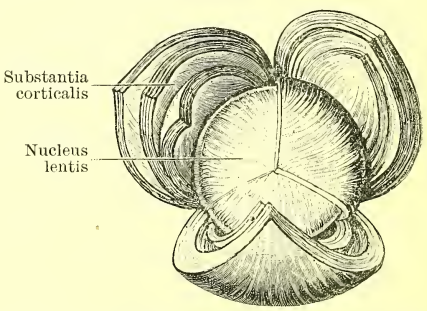


Fig. 571.—Lens hardened in Formalin and dissected to show its Concentric Laminæ (enlarged).

The lens substance (substantia lentis) consists of a soft outer part, the **substantia corticalis**, easily crushed between the finger and thumb, and of a dense central part,

the **nucleus lentis.** Faint lines (radii lentis) radiate from its anterior and posterior poles towards its equator. In the fœtus they are three in number, and form with each other angles of 120° (Fig. 572). From the anterior pole one ray ascends vertically and the other two diverge downwards, while from the posterior pole one ray descends vertically and the other two diverge upwards. In the adult the rays may be increased to six or more. They represent the free edges of a corresponding number of septa which dip into the substance of the lens, and along which the extremities of the different groups of lens fibres come into contact, and are attached by a clear, amorphous substance. The lens, when hardened, exhibits a series of concentrically arranged laminæ (Fig. 571), superimposed like the coats of an onion and attached to each other by a clear, amorphous substance. Each lamina is split along the radiating lines, and consists of a series of hexagonal, riband-like fibres, the fibræ lentis, which are adherent to each other by their margins; those of the deeper laminæ are smaller and serrated, but non-nucleated; while those of the superficial coats are larger and nucleated, but non-serrated. The fibres extend in a curved manner from the rays on the anterior surface to the rays on the posterior surface, but no fibre extends from pole to pole. Fibres which start at or near one pole end at or near the equator on the opposite surface, and *vice versa*, while the intervening fibres take up intermediate positions. Between the substantia lentis and the anterior part of the capsule there is a layer of nucleated columnar epithelial cells, the epithelium lentis. On being traced towards the equator its cells become gradually elongated and transformed into lens fibres, which, when fully formed, lose all trace of their nuclei, except in the more superficial laminæ. Each lens fibre represents, therefore, a greatly elongated columnar cell (Fig. 573).

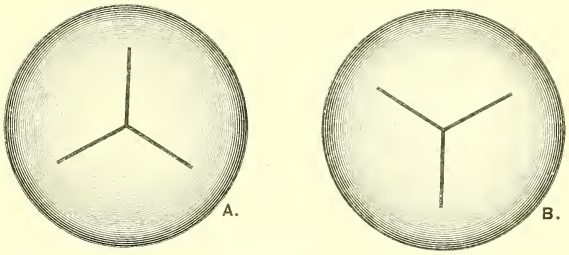


Fig. 572.—Diagrammatic Representation of the Radii Lentis of the Fœtal Lens.

A, Seen from the front; B, From behind.

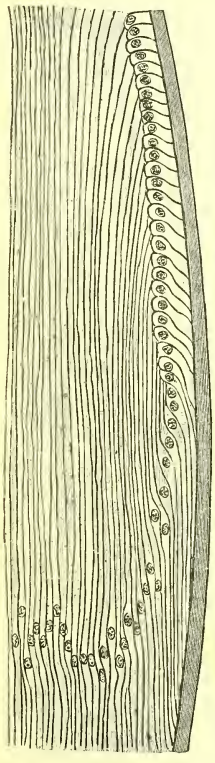


Fig. 573.

Section through the Equator of the Lens.

Showing the gradual transition of the epithelium into lens fibres (after Babuchin).

In the fœtus the lens is soft, of a pinkish colour, and nearly spherical; while in old age it becomes more flattened than in the adult, and, losing its transparency, assumes a yellowish tint.

Chambers of the Eye and Aqueous Humour (Fig. 558).—As already stated (p. 730), the space between the cornea and the lens is divided by the iris into two unequal parts, viz. the anterior chamber in front and the posterior chamber behind. These are filled by the **aqueous humour,** and, in the adult, communicate freely through the aperture of the pupil, but in the fœtus are separated from each other by the pupillary membrane. The **anterior chamber** (camera oculi anterior) is bounded in front by the cornea, behind by the iris and lens, whilst peripherally it communicates with the spaces of Fontana. The **posterior chamber** (camera oculi posterior) is triangular on section, and is bounded in front by the iris, behind by the circumferential part of the lens and its suspensory ligament; the base of the triangle, situated externally, corresponds with the thick, anterior extremities of the ciliary processes. It communicates with the recessus cameræ posterior and canal of Petit. The aqueous humour has a refractive index of about 1·336, and consists of about 98 per cent of water, with 1·4 per cent of sodium chloride and traces of albumen.

EYELIDS.

The **eyelids or palpebræ** are two movable cutaneous curtains situated in front of the eyeball, and named, from their position, upper and lower. The upper is the larger and more movable, being provided with a special elevator muscle, the m. levator palpebræ superioris. The interval between the lids is termed the **palpebral fissure** (rima palpebrarum), and measures transversely about 30 mm., but varies considerably in different individuals and in different races. When the eye is open the fissure is elliptical in shape, but when closed it assumes the form of a transverse slit, which lies on a level with the lower margin of the cornea. The two lids meet at the extremities of the fissure, and form the **outer** and **inner angles**, or **canthi**. Their free margins are flattened and are surmounted by eyelashes from the external

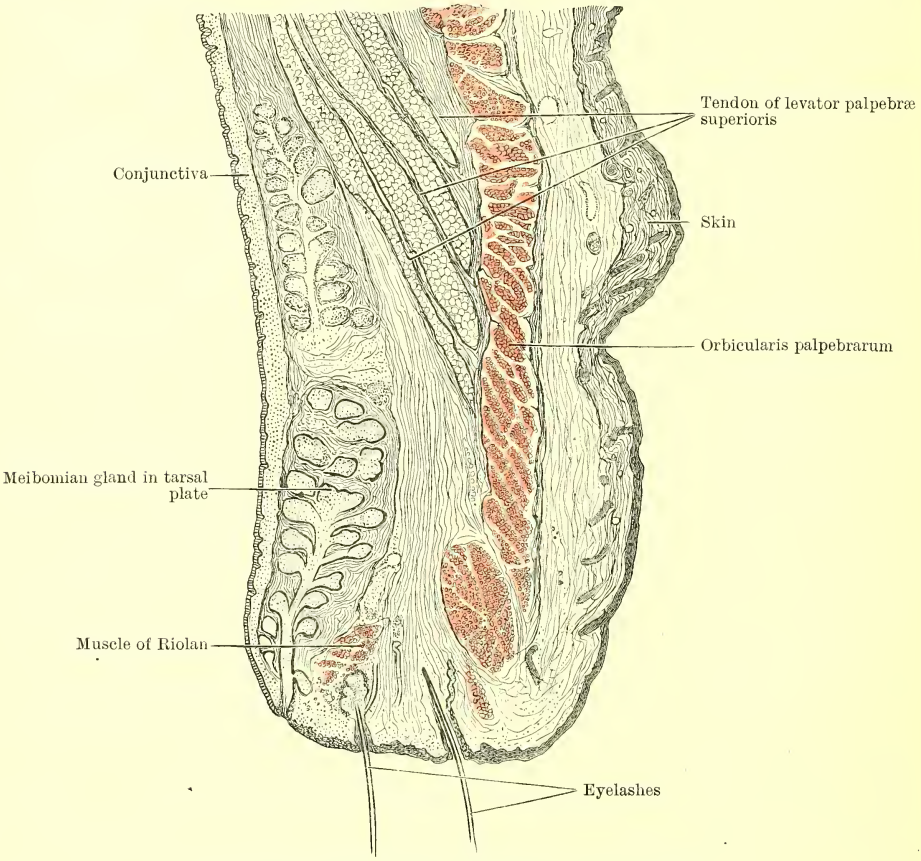


FIG. 574.—VERTICAL SECTION THROUGH UPPER EYELID.

canthus to a point about 5 mm. from the inner canthus—a point indicated by a small papilla, the **papilla lacrimalis**. Internal to this papilla the margins are rounded and destitute of eyelashes, and form the upper and lower boundaries of a triangular space, termed the **lacus lacrimalis**, which is occupied by a small pale-red body, the **caruncula lacrimalis**. This caruncula consists of a minute island of modified skin, and contains sweat glands, sebaceous glands, and fine hairs. Posteriorly the lids are lined by a mucous membrane, the conjunctiva, and are in contact with the eyeball, except near the inner canthus, where, between the eyeball and the caruncula lacrimalis, there intervenes a vertical fold of conjunctiva, the **plica semilunaris conjunctivæ**. This, which in many animals contains a plate of cartilage, is the representative of the membrana nictitans, or third eyelid of birds, etc.

In each lid there exists a framework of condensed fibrous tissue, which gives consistence and shape to the lid, and is termed the **tarsal plate or tarsus**. In front of the tarsus are the fibres of the orbicularis palpebrarum muscle and the

integument, while embedded in its posterior surface, and covered by the conjunctiva, are numerous modified sebaceous glands named the **tarsal or Meibomian glands**. The superior tarsal plate (tarsus superior) is larger than the inferior and of a half oval shape, with its greatest vertical diameter measuring about 10 or 11 mm. Its upper margin is thin and convex, and is continuous with the tendon of the levator palpebræ superioris muscle, while its lower edge is thick and straight. The inferior tarsal plate (tarsus inferior) is a thin, narrow strip, with a nearly uniform vertical diameter of about 5 mm. The extremities of the two plates are continuous with the **external and internal tarsal ligaments**. The external tarsal ligament is a narrow band attached to the malar bone; it divides, at the outer canthus, into upper and lower pieces which are fixed to the margins of the respective tarsal plates. The internal tarsal ligament is a strong band attached to the nasal process of the superior maxillary bone directly in front of the lachrymal groove; it divides at the inner canthus into two slips, one for either tarsal plate.

The eyelids are further strengthened by membranous expansions, termed the **superior** and **inferior palpebral ligaments**, which extend into them from the margin of the orbit. The superior ligament is continuous, along the upper margin of the orbit, with the pericranium and with the periosteal lining of the orbit, and blends below with the tendon of the levator palpebræ superioris. The inferior ligament is prolonged from the under edge of the inferior tarsal plate to the lower margin of the orbit, where it is continuous with the periosteum of the face and orbital floor. Externally the two palpebral ligaments fuse to form the external tarsal ligament, while internally they become thinned, and, separating from the internal tarsal ligament, are attached to the lachrymal bone behind the lachrymal sac. These two palpebral ligaments form a kind of septum or diaphragm, the **septum orbitale**, between the superficial and deep structures of the eyelids; this septum is perforated by the vessels and nerves, which extend from the orbital cavity to the face or scalp.

The skin covering the lids is thin and delicate, and is continuous, at their margins, with their conjunctival lining. It contains numerous small sweat glands and fine hairs, the latter being provided with sebaceous follicles. Branched pigment cells are present in the cutis, and pigment also exists in the deep layers of the epidermis. The subcutaneous tissue is loose and devoid of fat, and in it are found the fibres of the orbicularis palpebrarum muscle—a small separate bundle of which, termed the **muscle of Riolan**, occupies the margin of the lids behind the eyelashes. The **Meibomian glands**, or glandulæ tarsales, are elongated sebaceous glands with numerous lateral offshoots; they are embedded in the tarsal plates and filled with cubical epithelium. There are from twenty-five to thirty in the upper lid, and from twenty to twenty-five in the lower; they open by small ducts, about 1 mm. in length, along the lid margins behind the eyelashes; the ducts are lined by stratified epithelium placed on a basement membrane. Between the eyelashes and the muscle of Riolan are two or three rows of modified sweat glands, termed the **glands of Moll**; the blocking of a duct of one of these glands frequently gives rise to a stye.

H. Müller described a layer of non-striped muscle in each lid: in the upper extending from the tendon of the levator palpebræ superioris to the upper tarsal plate, and in the lower connecting the inferior tarsal plate with the inferior oblique muscle.

The tendon of the levator palpebræ superioris divides into three parts—an anterior, passing between the bundles of the orbicularis to the deep surface of the skin; a middle, attached to the superior tarsal plate; and a posterior, to the fornix conjunctivæ: there is no corresponding muscle in the lower lid. The eyelashes are curved, silky hairs which project from the free margins of the lids; in the upper lid they are longer and more numerous than in the lower, and are curved upwards, while those of the lower lid are bent downwards.

Conjunctiva.—This is the name applied to the mucous membrane which lines the back of the lids (**tunica conjunctiva palpebrarum**), and is continued on to the front of the eyeball (**tunica conjunctiva bulbi**). The line along which it is reflected from the lids on to the globe of the eye is termed the **fornix conjunctivæ**. The palpebral portion adheres intimately to the tarsal plate and presents numerous papillæ. It is covered by a layer of columnar epithelial cells, beneath the bases

of which are small flattened cells. Near the fornix a number of acino-tubular glands, much more plentiful in the upper than in the lower lid, open on its free surface. The conjunctiva bulbi is thinner than that lining the lids, and is loosely attached to the sclera by submucous tissue. The plica semilunaris conjunctivæ has already been referred to (p. 738). On the cornea the conjunctiva is represented merely by the stratified epithelium already described (p. 726).

Vessels and Nerves.—The chief **arteries** of the eyelids are the superior and inferior palpebral branches of the ophthalmic, which pierce the septum orbitale above and below the internal tarsal ligament, and run tortuously outwards in the corresponding lid near its free margin. On reaching the region of the outer canthus they anastomose with each other and with twigs from the lachrymal, superficial temporal, and transverse facial arteries, and in this way an arch is formed in each lid (upper and lower tarsal arches). Secondary smaller arches are found, one above the primary arch in the upper lid, and another below that of the lower lid, while the upper lid also receives branches from the supraorbital and frontal arteries. The **veins** are arranged in two sets : (*a*) subconjunctival or retrotarsal, opening into the muscular tributaries of the ophthalmic vein, and (*b*) pretarsal, into the angular and superficial temporal veins. The **lymphatics**, like the veins, form pre- and retrotarsal networks, which communicate with each other through the tarsal plates. The lymph is chiefly drained into the perauricular and parotid lymphatic glands, but partly, by vessels which accompany the facial vein, into the submaxillary lymphatic glands. The **sensory nerves** of the eyelids are supplied by the fifth cranial nerve—the upper lid chiefly by the supraorbital and supratrochlear branches of the ophthalmic ; the lower, by the infraorbital branch of the superior maxillary. The region of the outer canthus receives some filaments from the lachrymal nerve, that of the inner from the infratrochlear. These sensory nerves form a marginal plexus behind the orbicularis palpebrarum muscle. The levator palpebræ muscle is supplied by the third cranial nerve and the non-striped fibres of the lids by the sympathetic.

LACHRYMAL APPARATUS.

The **lachrymal apparatus** (apparatus lacrimalis) consists of : (1) the lachrymal gland, which secretes the tears ; (2) the lachrymal canals, by which they are drained from the front of the globe ; and (3) the lachrymal sac and nasal duct, which convey them into the nasal cavity.

The **lachrymal gland** is a flattened, oval body situated in the upper and outer part of the orbital cavity, and consists of two portions—orbital and palpebral—imperfectly separated from each other by the expansion of the tendon of the levator palpebræ superioris muscle. The **orbital** portion, or **glandula lacrimalis superior**, is firm and much larger than the palpebral part ; it measures transversely about 20 mm., and sagittally from 12-14 mm. It occupies the fossa lacrimalis on the inner aspect of the external angular process of the frontal bone, and is fixed by fibrous bands to its periosteum, while its inferior surface is in contact with the levator palpebræ superioris and external recti muscles which intervene between it and the globe of the eye. The smaller, **palpebral portion**, or **glandula lacrimalis inferior**, consists of small, loosely aggregated lobules. It lies below and in front of the orbital portion, and projects into the posterior part of the upper eyelid, where its deep surface is in contact with the conjunctiva. The ducts which drain the orbital portion are from three to five in number ; they pass between the lobules of the palpebral portion, and open at the upper and outer part of the fornix conjunctivæ. The ducts of the palpebral portion number from three to nine ; some of them join those from the orbital part, while others open separately at the fornix conjunctivæ. The lachrymal gland has a structure similar to that of the parotid, and is supplied by the sympathetic and lachrymal nerves and by the lachrymal artery, while its veins are drained into the ophthalmic vein.

The **lachrymal canals** (ductus lacrimales) commence by minute orifices, termed the **puncta lacrimalia**, at the apices of the papillæ lacrimales already referred to (p. 738). The upper canal is the smaller of the two, and at first ascends for a short distance, and then runs inwards and slightly downwards ; the lower descends for a short distance and then runs horizontally inwards. At the angle where they change their direction each is dilated into an ampulla (ampulla ductus lacrimalis). They occupy the margins of the lids, where these bound the lacus lacrimalis, and the two canals open close together into the outer and fore-part of the lachrymal sac, a little below its middle ; sometimes they open separately into a pouch-like dilatation of the sac, termed the sinus of Maier. Each canal is lined by a

stratified epithelium placed on a tunica propria, outside which is a layer of striped muscular fibres derived from the tensor tarsi muscle. These muscular fibres are arranged somewhat spirally around the canals, but at the bases of the papillæ they are circular in direction and form a species of sphincter. On contraction they serve to empty the contents of the lachrymal canals into the lachrymal sac.

The **lachrymal sac** and **nasal duct** together form the passage by which the tears are conveyed from the lachrymal canals to the nose.

The **lachrymal sac** (saccus lacrimalis) is the upper expanded part of the passage, and measures from 12-15 mm. in length, about 7 mm. antero-posteriorly, and from 4-5 mm. transversely. It lies in the groove formed by the lachrymal bone and nasal process of the superior maxilla, and ends above in a rounded, blind extremity or fundus, while it narrows below into the nasal duct. Here a fold of mucous membrane, named the valve of Beraud, together with a laterally directed pouch, the sinus of Arlt, are sometimes present. Near its superior extremity it is crossed in front by the internal tarsal ligament, from the upper and lower edges of which the orbicularis palpebrarum takes origin, while behind it is the tensor tarsi muscle, or muscle of Horner.

The **nasal duct** (ductus naso-lacrimalis) averages about 18 mm. in length, and has a diameter of from 3-4 mm. Rather narrower near its middle than at its upper and lower extremities, it is directed downwards and slightly backwards, and opens into the inferior meatus of the nose at the junction of its anterior with its posterior three-fourths, *i.e.* a distance of 30-35 mm. from the posterior boundary of the nostril. Its lower orifice is somewhat variable in form and position, and is occasionally duplicated. It is frequently guarded by a fold of mucous membrane, termed the **valve** or **plica lacrimalis of Hasner**. Through this orifice the mucous lining of the duct is continuous with that of the nose. The mucous membrane of the duct is thrown into inconstant folds, several of which have been described as valves. Its epithelium is columnar and in part ciliated; opening into the lower part of the duct are numerous glands similar to those in the nasal mucous membrane. The nerves of the lachrymal canals and sac are derived from the infratrochlear branch of the nasal; their arteries from the inferior palpebral and nasal. The veins of the nasal duct are large and numerous, forming a sort of erectile tissue similar to that in the nose.

Development of the Eye.

The retina and optic nerve are developed from a hollow outgrowth of the fore-brain, termed the **optic vesicle** (see pp. 478 and 595). This extends towards the side of the head, and its

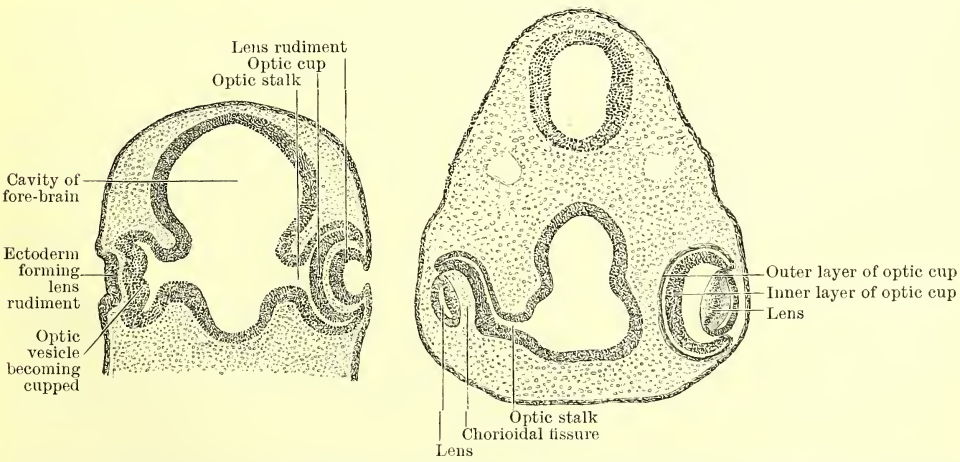


Fig. 575.—Sections through Portions of the Heads of Fœtal Rabbits, to illustrate the connexion of the optic cup with the fore-brain, and the invagination of the ectoderm to form the lens.

connexion with the brain is gradually elongated to form the **optic stalk**. The ectoderm overlying the optic vesicle becomes thickened, invaginated, and finally cut off as a hollow

island of cells, which is developed into the lens and is named the **lens vesicle**. This lens rudiment indents the outer and lower part of the optic vesicle, which now assumes the form of a cup (**optic cup**), lined by two layers of cells continuous with each other at the margin of the cup. The inner of these strata, thicker than the outer, is named the **retinal layer**, and becomes differentiated into the nervous and supporting elements of the retina; while the outer, named the **pigmentary layer**, forms its pigmented epithelium. The edge of the optic cup extends in front of the equator of the lens, and bounds the future aperture of the pupil. In front of the lens, and also opposite its equator, the retinal layer is thin, and represented only by a stratum of columnar cells which becomes closely applied to the pigmentary layer, the two forming the pars ciliaris and pars iridica retinæ. The indentation of the optic cup extends as a groove for some distance along the postero-inferior aspect of the optic stalk, forming what is termed the **chorioidal fissure** (Fig. 576). Through this fissure the mesoderm passes inwards between the lens and the retina to form the vitreous body, while the arteria centralis retinæ also becomes enclosed in it and so gains its future position in the centre of the optic nerve. The arteria centralis is prolonged forwards from the porus opticus through the vitreous body, as a cone of branches, as far as the back of the lens. By the fifth or sixth month all these branches have disappeared except one, the **arteria hyaloidea**, which persists until the last month of fœtal life, when it also atrophies, leaving only the **canalis hyaloideus** to indicate its position.

The lens rudiment, at first in contact with the ectoderm, from which it is derived, soon becomes separated from it by mesoderm, and then consists of a rounded vesicle lined by epithelium. The epithelium which lines the anterior part of the vesicle remains as a single layer of cells—the anterior lens epithelium of the adult. The cells lining the posterior part of the vesicle become elongated into lens fibres, and by the forward growth of these the cavity of the vesicle is obliterated. This elongation into lens fibres is greatest at the centre of the lens, while near the equator the fibres are shorter, and here the gradual transition between the anterior epithelium and the lens fibres is seen (Fig. 573). The lens becomes enveloped in a vascular tunic, which receives its vessels from the arteria centralis retinæ and from the vessels of the iris. The front part of this tunic forms the membrana pupillaris, and this, like the rest of the tunic, disappears before birth.

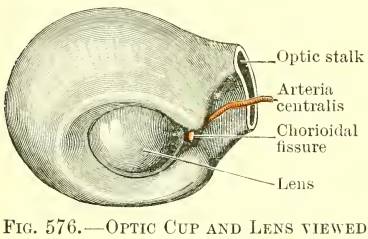


FIG. 576.—OPTIC CUP AND LENS VIEWED FROM BEHIND AND BELOW, to show formation of chorioidal fissure and enclosure of the arteria centralis retinæ (from model by Ziegler).

The hollow stalk of the optic cup becomes solid by the thickening of its walls and the obliteration of its cavity, and, acquiring nerve-fibres, becomes the optic nerve. These nerve-fibres are mostly centripetal, and are derived from the nerve-cells of the retina; but a few are centrifugal and have their origin in the brain. The further development of the retina resembles, in certain respects, that of the spinal cord.

Cameron states ("The Development of the Retina in Amphibia," *Journ. Anat. and Physiol.*, London, vol. xxxix.) that in the early stages of the development of the inner or retinal layer of the optic cup all the structures, described by His as being present in the spinal cord of the human embryo, are to be found, viz. (*a*) spongioblasts, (*b*) germinal cells, and (*c*) neuroblasts.

The spongioblasts undergo ramification and form a network or myelospongium, and also give rise to the inner and outer limiting membranes; the latter is next the original cavity of the optic vesicle, and therefore corresponds to the inner limiting membrane of the spinal cord. The spongioblasts also form the groundwork of the inner and outer molecular layers into which the processes of the neuroblasts grow and arborise.

The germinal cells are always situated beneath the external limiting membrane, and by their division give rise to the neuroblasts. The first-formed neuroblasts are larger than those of succeeding generations, and are found in the site of the future ganglionic layer. The germinal cells in the middle of the convexity of the retinal cup cease to divide at an early stage of development, and become directly transformed into the rod and cone cells from which the rods and cones develop as processes; hence these structures appear first over the middle of the convexity of the retina, and gradually extend towards the margin of the retinal cup.

The nuclei of the retinal neuroblasts undergo a progressive diminution in size—in some cases to one-fourth of that of their earlier stages. Cameron, after a careful study of the neuroblasts, not only in the retina, but in the wall of the cerebral vesicle and spinal cord, is of opinion that the neuroblastic nuclei are destitute of a protoplasmic investment, and that what has been described as a zone of "clear protoplasm" surrounding these nuclei during the process of karyokinesis is simply the achromatic nuclear substance set free by the disappearance of the nuclear membrane; and, further, that the processes which grow out from the neuroblasts in reality issue from the substance of the nuclei and thus cause the gradual diminution in size of the latter. "The processes of the retinal 'ganglion-cells' and of the cells of the inner nuclear layer first show

themselves as protrusions of the nuclear contents, while the rods and cones are at first also protrusions of the nuclei of the external nuclear layer. The rod and cone elements, when they first appear, do so as perfectly clear spherical globules consisting of nothing more than nuclear achromatin. The axis-cylinders of the optic nerve arise as processes of the nuclei in the ganglionic layer, and the great difficulty which is experienced in staining the individual fibres of the retinal nerve-fibre layer is due to the fact that they are composed of the achromatic nuclear substance of the ganglionic nuclei. The origin of the axis-cylinders from these nuclei supports the contention of those who insist on the fact that the axis-cylinder process of a nerve-cell can be traced right into the nucleus of that cell."

The molecular layers make their appearance as plexuses of myelospongium. The internal molecular layer is first developed at the centre of the retinal cup, and gradually extends towards the cup margin, and into it the processes from the nuclei on either side grow and ramify. The rod and cone fibres, and the outer processes of the internal nuclear layer, grow into and arborise within the external molecular layer.

The most interesting points with reference to the development of the nuclear layers are, (1) the extrusion of the various processes from the nuclei as already described, and (2) the free manner in which these nuclei multiply by *direct* division during the metamorphosis. It is interesting to note that the retinal nuclei are formed during the early stages by mitotic or indirect division of the germinal cells, while later they appear capable of multiplying by amitotic or direct division only.

The first evidences of the rods and cones are in the form of clear, absolutely achromatic globules, which lie between the nuclei of the external nuclear layer and the outer limiting membrane. Whenever these are protruded beyond this membrane they grow with great rapidity, and exert an influence on the retinal pigment cells, causing them to protrude their processes, the pigment of which they seem to digest and absorb, since they now stain deeply with iron-alum-hæmatoxylin. This gives us a clue to the mode by which the rhodopsin function of the rods in the adult is conducted, for these structures actually owe their growth and development to the ingestion of pigment from the pigment-cell processes.

The condensed mesoderm surrounding the optic cup becomes the sclera and chorioid. In the portion of the mesoderm which lies in front of the lens a cleft-like fissure appears, and divides it into a thick anterior and a thin posterior layer. The former becomes the substantia propria of the cornea; the latter, the stroma of the iris and anterior part of the vascular tunic of the lens. The fissure represents the future anterior chamber, and its lining cells form the layer of endothelium on the back of the cornea and front of the iris.

The **eyelids** arise as two integumentary folds above and below the cornea, each being covered on both its surfaces by the ectoderm. By the third month the folds meet and unite with each other at their edges, the eyelids being only permanently opened shortly before birth; in many animals they are not opened until after birth. The ectoderm forms the epithelium of the conjunctiva and the stratified epithelium of the cornea. It is also invaginated at the lid margins to form the hair follicles and the lining cells of the Meibomian glands and glands of Moll, and, at the fornix conjunctivæ, to form the lining of the alveoli and ducts of the lachrymal gland.

The **nasal duct, lachrymal sac, and canals** represent the remains of the furrow which extends from the inner angle of the eye to the nasal cavity between the superior maxillary and lateral nasal processes (p. 40). It is at first filled by a solid rod of cells, which becomes hollowed out to form the duct and canals.

THE EAR.

The ear or organ of hearing (organon auditus, Fig. 577) consists of three portions —external, middle, and internal—the last constituting its essential part, as within it are distributed the peripheral terminations of the auditory nerve.

EXTERNAL EAR.

The **external ear**[1] includes —(*a*) the pinna or auricula, attached to and projecting from the side of the head; and (*b*) the passage or external auditory meatus (meatus acusticus externus), leading inwards from the most depressed part of the pinna as far as the tympanic membrane or outer wall of the middle ear.

The Pinna.

The **pinna** or **auricula** (Fig. 578) presents two surfaces, outer and inner, the latter forming an angle (cephalo-auricular angle) of about 30°, with the side of the

[1] Although it is usual to speak of the external, middle, and internal ear, it would be more correct to use the terms external, middle, and internal *portions* of the ear.

head. The outer surface is irregularly concave, but presents several well-marked elevations and depressions. The deepest of the depressions is situated near its middle, and is named the **concha** (concha auriculæ). It is divided by an almost transverse ridge, the **crus helicis**, into an upper, smaller, and a lower, larger portion: the former is termed the **cymba conchæ**; the latter, which leads into the meatus, the **cavum conchæ**. Anteriorly, the crus helicis is continuous with the margin of the pinna or **helix**, which is folded over, in the greater part of its extent, like the rim of a hat, and is directed at first upwards, and then backwards and downwards, to become gradually lost a little below the middle of the pinna. Near the point where the helix begins to turn downwards a small tubercle, the **tuberculum superius** (Darwini), is often seen; it will be again referred to. In front of the descending part of the helix is a second elevation, the **antihelix**. Single below, it divides superiorly into two limbs, termed the **crura antihelicis**, between which is a triangular depression, the **fossa of the antihelix**, or **fossa triangularis**. The elongated furrow between the helix and antihelix is named the **fossa of the helix** or **scapha**. The concavity of the concha is overlapped in front by a tongue-like process, the **tragus**, and behind by a triangular projection, the **antitragus**; the notch, directed downwards and forwards between these two processes, is named the **incisura intertragica**. The tragus really consists of two tubercles, the upper of which constitutes the **tuberculum supratragicum** of His, and is separated from the helix by a groove, the **sulcus auris anterior**. The **lobule** (lobulus auriculæ) is situated below the incisura intertragica, and is the most dependent part of the pinna.

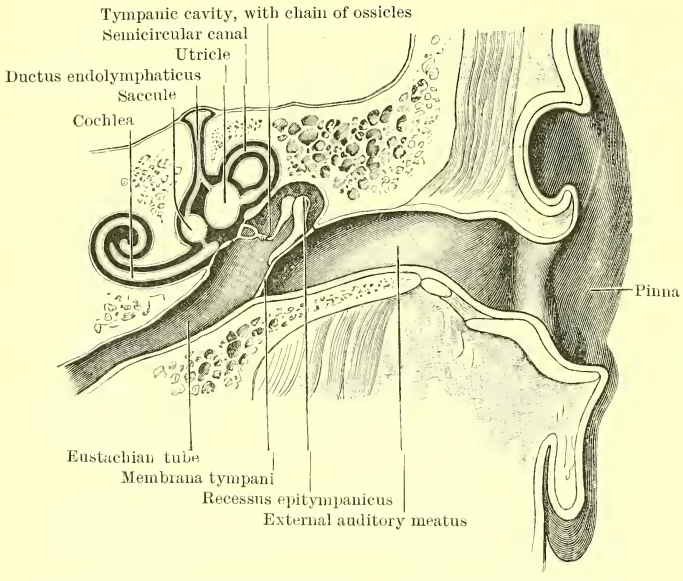


Fig. 577.—Diagrammatic View of the Organ of Hearing.

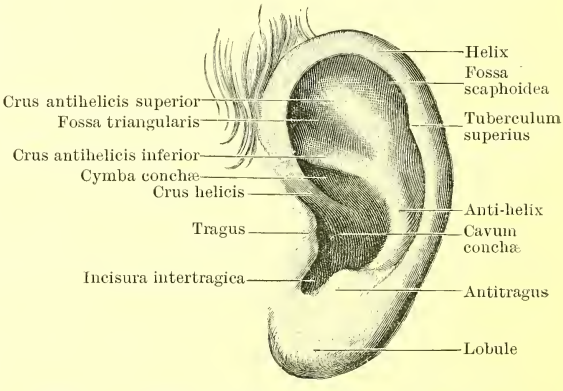


Fig. 578.—View of Outer Surface of Left Pinna (half natural size).

The inner or cranial surface is also irregular, and presents elevations corresponding to the depressions on its outer surface, *e.g.* **eminentia conchæ, eminentia triangularis**, etc.

The pinna is usually smaller and more finely modelled in the female than in the male, but presents great variations in size and shape in different individuals. In the newly-born child its length is about one-third of that of the adult, while it increases slightly in length and breadth in old age.

The relation of the width to the height is termed the auricular index, and is expressed as follows:—

$$\frac{\text{width of pinna} \times 100}{\text{length of pinna}} = \textbf{Auricular index.}$$

This index is less in white than in dark races.

The **cephalo-auricular angle** may be practically absent, as in those cases where the skin of the head passes directly on to the outer surface of the pinna, or it may be increased to nearly a right angle, so that the outer surface of the pinna looks directly forwards. The **tuberculum superius**, the significance of which was recognised by Darwin, is a somewhat triangular prominence which projects forwards when the helix is well rolled over, but backwards and upwards when the incurving of the helix has been arrested. More frequently present in men than in women, it is of developmental interest since it has been shown to be well marked at the sixth month of fœtal life, the entire pinna, at this stage, resembling in appearance that of the adult macaque.

The **lobule** may be small and sessile or considerably elongated; it may adhere to the skin of the cheek (*i.e.* webbed), or may tend to bifurcate at its lower extremity.

Structure of the Pinna.—The greater part of the pinna consists of a lamella of yellow fibro-cartilage, the **cartilago auriculæ**; the cartilage is, however, absent from the lobule, which is composed of fat and connective tissue. When laid bare, the cartilaginous lamella (Figs. 579, 580) presents, in an exaggerated condition, all the inequalities of the pinna, and is seen to be prolonged inwards, to form a considerable portion of the external auditory meatus. The cartilage of the helix projects anteriorly as a conical eminence, the **spina helicis**, whilst its inferior extremity extends downwards as a tail-like process, the **cauda helicis**, which is separated from the lower part of the antitragus by a fissure, termed the **fissura antitragohelicina**. The cartilage of the pinna is continuous with that of the meatus by a narrow **isthmus** (isthmus cartilaginis auris) measuring from 8-9 mm. in breadth. This isthmus corresponds externally with the deepest part of the incisura intertragica, and internally it forms the outer boundary of a deep fissure, the **incisura terminalis auris**, which separates the cartilage of the meatus from that of the concha. The upper edge of the tragus fits into an angle below the crus helicis.

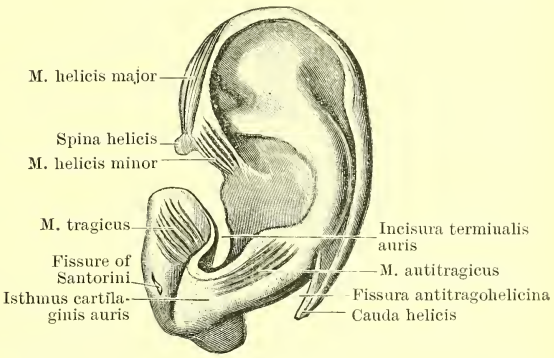


Fig. 579.—Outer Surface of Cartilage of Pinna (one-half natural size).

If the incisura terminalis auris, together with the isthmus and the incisura intertragica, be taken as representing the boundary between the cartilage of the pinna and that of the meatus, it follows that the tragus really forms a part of the meatal cartilage.

On the cranial aspect of the cartilage (Fig. 580) the eminences produced by the concha and fossa triangularis are separated by a transverse furrow, the **sulcus antihelicis transversus**, corresponding with the crus antihelicis inferior; further, the eminentia conchæ is crossed horizontally by a groove, the **sulcus cruris helicis**, and almost vertically by a slight ridge, the **ponticulus**: the latter indicates the attachment of the M. auricularis posterior.

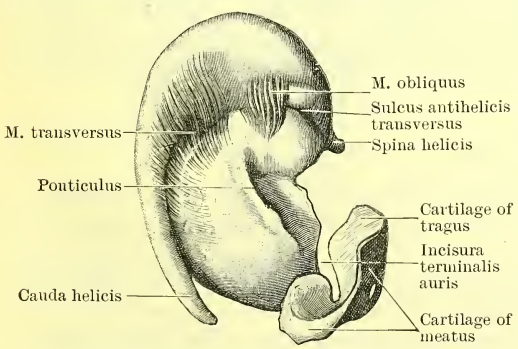


Fig. 580.—Inner Surface of Cartilage of Pinna (one-half natural size).

In addition to the fissures described, others, termed the **fissures of Santorini**, are found, usually one in the tragus and one or more in the cartilage of the meatus.

Ligaments of the Pinna.—The cartilage of the pinna is attached to the skull by two fibrous bands which form its extrinsic ligaments, viz.: an *anterior*, stretching from the zygoma to the spina helicis and tragus; and a *posterior*, passing from the eminentia conchæ and upper wall of the meatus to the mastoid

process. Small ligamentous bands pass between individual parts of the pinna, and form what are termed its intrinsic ligaments.

Muscles of the Pinna (Figs. 579, 580).—The muscles of the pinna are divided into two groups, *extrinsic* and *intrinsic*. The extrinsic muscles pass from the pinna to the skull or scalp, and are described in the section on Myology. The intrinsic muscles, on the other hand, are confined to the pinna and are six in number, four on its outer and two on its cranial aspect.

(*a*) *On the outer surface* (Fig. 579)—

1. **M. helicis major**, passes upwards from the spina helicis along the ascending part of the helix. 2. **M. helicis minor**, covers the crus helicis. 3. **M. tragicus**, quadrangular in shape, consists of fibres running vertically over the greater part of the tragus. Some of its fibres are prolonged upwards to the spina helicis and constitute the m. pyramidalis. 4. **M. antitragicus**, covers the antitragus and passes obliquely upwards and backwards as far as the antihelix and cauda helicis.

(*b*) *On the cranial surface* (Fig. 580)—

1. **M. transversus auriculæ**, consists of scattered fibres, which stretch from the eminentia conchæ to the convexity of the helix. 2. **M. obliquus auriculæ** (Tod), comprises a few fasciculi, which run obliquely or vertically across the furrow corresponding with the crus antihelicis inferior. A small muscle, the stylo-auricularis, sometimes extends from the root of the styloid process to the cartilage of the meatus.

Skin of the Pinna.—The skin covering the pinna is thin and smooth, and is prolonged inwards, in the form of a tube, as a lining to the external auditory meatus. It adheres firmly, on the outer surface of the pinna, to the subjacent perichondrium. Hairs are well developed on the tragus and antitragus, and also in the incisura intertragica, forming the **barbula hirci**, which guard the entrance to the concha. Soft downy hairs are found over the greater part of the pinna and point towards Darwin's tubercle. Sebaceous glands, present on both surfaces of the pinna, are most numerous in the concha and fossa triangularis. Sweat glands are found on both surfaces, but are much more numerous on the cranial aspect.

Vessels of the Pinna.—The **arteries** for the pinna are derived—(*a*) from the superficial temporal, which sends two or three branches to the outer surface; and (*b*) from the posterior auricular, which gives three or four branches to the cranial surface. From the latter two sets of twigs are prolonged to the outer surface, one turning round the free margin of the helix, and the other passing through small fissures in the cartilage. The **veins** from the outer surface open into the superficial temporal vein; those from the cranial surface chiefly join the posterior auricular vein, but some communicate with the mastoid emissary vein. The **lymphatics** take three directions, viz.: (*a*) forwards to the parotid lymphatic glands, and especially to the preauricular gland in front of the tragus; (*b*) downwards to the lymphatic glands which accompany the external jugular vein, and to the glands under the sternomastoid; and (*c*) backwards to the mastoid lymphatic glands.

Nerves of the Pinna.—The muscles of the pinna are supplied by the seventh cranial nerve. The skin receives its sensory nerves from—(*a*) the great auricular, which supplies nearly the whole of the cranial surface, and sends filaments in company with the branches of the posterior auricular artery to the outer surface; (*b*) the auriculo-temporal, which supplies the tragus and ascending part of the helix; (*c*) the small occipital, which sends a branch to the upper part of the cranial surface.

External Auditory Meatus.

The **external auditory meatus** (meatus acusticus externus) (Figs. 580, 581) is the passage leading inwards from the concha as far as the membrana tympani. Its average length, measured from the bottom of the concha, is about one inch (24 mm.), but, if measured from the level of the tragus, nearly one inch and a half (35 mm.) On account of the obliquity of the membrana tympani its anterior and inferior walls are longer than the posterior and superior. The tube consists of two parts, viz.: (*a*) an external **fibro-cartilaginous portion**, the pars cartilaginea, having a length of about 8 mm.; and (*b*) an internal **osseous portion**, the pars ossea, measuring about 16 mm., and formed by a portion of the temporal bone. The entire meatus forms a somewhat S-shaped bend (Fig. 582), and may be divided into

three portions, viz.: (1) **pars externa**, directed inwards, forwards, and slightly upwards for about 7 mm.; (2) **pars media**, inclining inwards and backwards for about 5 mm.; (3) **pars interna**, the longest of the three, passing forwards, inwards, and slightly downwards. On transverse section the canal is seen to be elliptical, its greatest diameter having an inclination downwards and backwards. Widest at its outer extremity, it becomes somewhat narrower at the inner end of the pars cartilaginea; once more expanding in the outer part of the pars ossea, it is again constricted near the inner end of the latter, where its narrowest part, or **isthmus**, is found at a distance of about 19 mm. from the bottom of the concha. The inner extremity of the meatus is nearly circular and is closed by the membrana tympani.

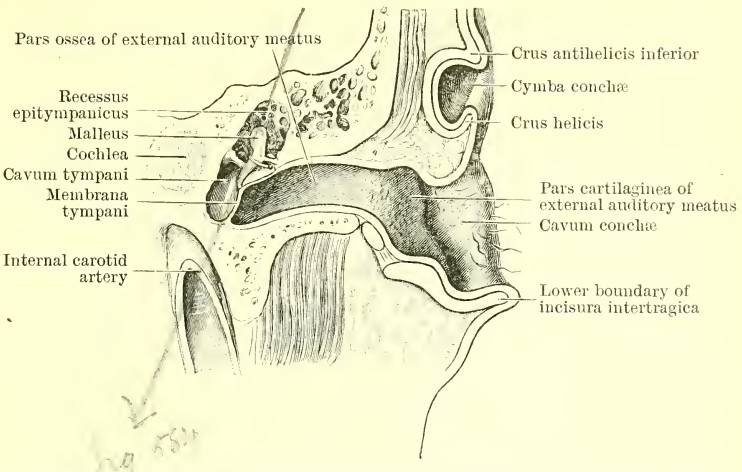


FIG. 581.—VERTICAL TRANSVERSE SECTION OF RIGHT EAR; ANTERIOR HALF OF SECTION, viewed from behind (natural size).

Bezold gives the diameters of the meatus as follows:—

	Greatest.	Least.
At the commencement of the pars cartilaginea. . .	9·08 mm.	6·54 mm.
At the end ,, ,, ,, . . .	7·79 mm.	5·99 mm.
At the commencement of the pars ossea . . .	8·67 mm.	6·07 mm.
At the end ,, ,, ,, . . .	8·13 mm.	4·60 mm.

The lumen of the pars cartilaginea is influenced by the movements of the lower jaw, being increased when the jaw is depressed. This can be easily verified by inserting a finger into the meatus, and then alternately opening and shutting the mouth.

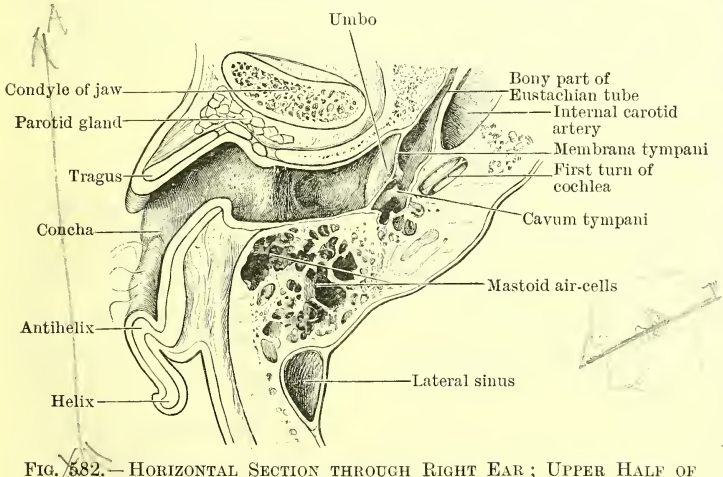


FIG. 582.—HORIZONTAL SECTION THROUGH RIGHT EAR; UPPER HALF OF SECTION seen from below (natural size).

The condyle of the jaw lies in front of the pars ossea, while between the jaw and the pars cartilaginea there intervenes a portion of the parotid gland. Below the meatus is the retro-mandibular part of the parotid gland. Behind the pars ossea, and separated from it by a thin plate of bone, are the mastoid air-cells.

Structure of the Meatus.—The cartilage of the meatus, directly continuous with that of the pinna, is folded on itself to form a groove, opening upwards and backwards, the margins of which are connected by fibrous tissue. The inner end of the cartilage is firmly fixed to the outer margin of the bony meatus, whilst its outer extremity is continuous with the cartilage of the tragus (*vide* p. 745). A couple of

fissures, the **fissures of Santorini**, exist in the anterior portion of the cartilage of the meatus, and are filled by fibrous tissue. In the outer part of the meatus the cartilage forms about three-fourths of its circumference; but, on passing inwards, the proportion of cartilage to fibrous tissue diminishes, with the result that near the inner end of the pars cartilaginea the cartilage forms merely a part of the anterior and lower boundaries of the canal.

The osseous portion (pars ossea) of the meatus is described on p. 117; but it may be well to state here that in the newly-born child it is represented only by an incomplete ring of bone, the **annulus tympanicus**, together with a small portion of the squamous temporal, which articulates with, and bridges over the interval between, the extremities of the ring superiorly. In the concavity of the annulus is a well-defined groove, the **sulcus tympanicus**, in which the circumference of the membrana tympani is fixed. On the inner aspect of the anterior part of the annulus, a little below its free extremity, a groove, the **sulcus malleolaris**, is directed downwards and forwards. It transmits the processus gracilis and anterior ligament of the malleus, the tympanic artery and the chorda tympani nerve. It is limited above by a well-marked ridge, the **crista spinarum** of Henle, which ends in front and behind in a spinous process (**spina tympanica anterior and posterior**). Below the sulcus malleolaris there is a second, less prominent ridge, the **crista tympanica** of Gruber, which subsequently unites with a process of the tegmen tympani, and so shuts off the canalis musculo-tubarius from the Glaserian fissure. A fibrous plate, the **tympanic fibrous plate** (Symington), intervenes between the annulus tympanicus and the inner end of the cartilage of the meatus, and into this plate the bony ring extends. The bony outgrowth does not, however, proceed uniformly throughout its circumference, but occurs most rapidly in the anterior and posterior parts of the ring. These outgrowths fuse about the end of the second year of life, so as to surround a foramen in the floor of the meatus (**foramen of Huschke**), which is usually closed by the fifth year, but persists until adult life in some 19 per cent of skulls (Bürkner).

The lumen of the meatus in the newly-born child is extremely small: its outer part is funnel-shaped; its inner a mere slit, bounded below by the tympanic fibrous plate and above by the obliquely-placed membrana tympani.

The **skin** which envelopes the pinna lines the entire meatus, and covers also the outer surface of the tympanic membrane. It is thick in the pars cartilaginea, and contains fine hairs and sebaceous glands, the latter extending inwards for some distance along the postero-superior wall of the pars ossea. The sweat glands are enlarged and of a brownish colour; they constitute the **glandulæ ceruminosæ** and secrete the ear wax or cerumen.

Vascular and Nervous Supply of the Meatus.—The meatus receives its blood-supply from the posterior auricular and superficial temporal arteries, and also from the deep auricular branch of the internal maxillary artery, the last distributing some minute branches to the membrana tympani. The **veins** open into the external jugular and internal maxillary veins, and also into the pterygoid plexus, while the **lymphatics** have a similar mode of termination to those of the pinna. **Sensory nerves** are supplied to the meatus by the auriculo-temporal branch of the fifth and by the auricular branch of the vagus.

MIDDLE EAR OR TYMPANIC CAVITY.

The **tympanic cavity** (cavum tympani) is a small air chamber in the temporal bone, which intervenes between the membrana tympani and the outer wall of the internal ear or labyrinth (Figs. 581, 582). Lined by mucous membrane, it contains a chain of ossicles (ossicula auditus) which reaches from its outer to its inner wall, and by means of which the vibrations of the membrana tympani are transmitted across the cavity to the internal ear. Attached to the ossicles are several ligaments, together with a pair of small muscles, while certain nerves are either distributed to the cavity or pass through it.

The tympanic cavity consists of two portions: (1) The **tympanum proper**, or **atrium**, lying immediately to the inner aspect of the membrana tympani; and (2) the **recessus epitympanicus**, lying above the level of the membrane and containing the greater part of the incus and the upper half of the malleus. Including this recess, the vertical and antero-posterior diameters of the tympanic cavity are rather more than half an inch (15 mm.) The distance between its outer and inner walls is about 6 mm. above and 4 mm. below, while at its central part, owing to the bulging of the two walls towards the cavity, it measures only from $1\frac{1}{2}$ to 2 mm.

The tympanic cavity presents for examination a roof, a floor, and four walls, viz. anterior, posterior, external, and internal.

The **roof** (Fig. 583) (paries tegmentalis) is formed by a thin plate of bone, the **tegmen tympani,** constituting a portion of the upper surface of the petrous-temporal. It extends backwards so as to cover in the mastoid antrum, and forwards, to form

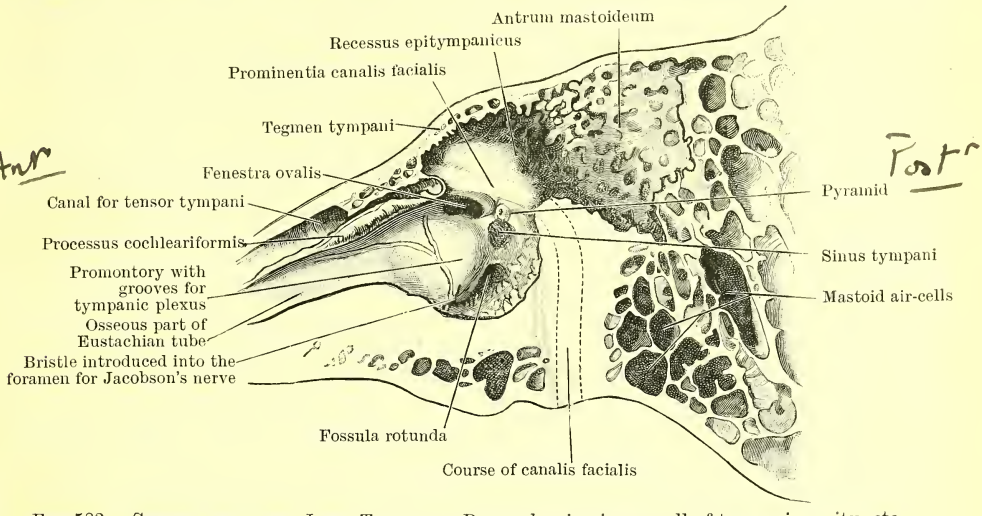


FIG. 583.—SECTION THROUGH LEFT TEMPORAL BONE, showing inner wall of tympanic cavity, etc.

the roof of the canal for the tensor tympani muscle. It separates the tympanum and antrum from the cranial cavity, and may contain a few air-cells, whilst occasionally it is partly deficient. In the child its outer edge corresponds with the petro-squamous suture. The **floor** (fundus tympani seu paries jugularis) is narrower than the roof, and consists of a thin plate of bone which separates the cavity from the fossa jugularis; anteriorly, it extends upwards and becomes continuous with the posterior wall of the carotid canal. The inner orifice for Jacobson's nerve, or tympanic branch of the glosso-pharyngeal, is seen near the junction of the floor with the inner wall.

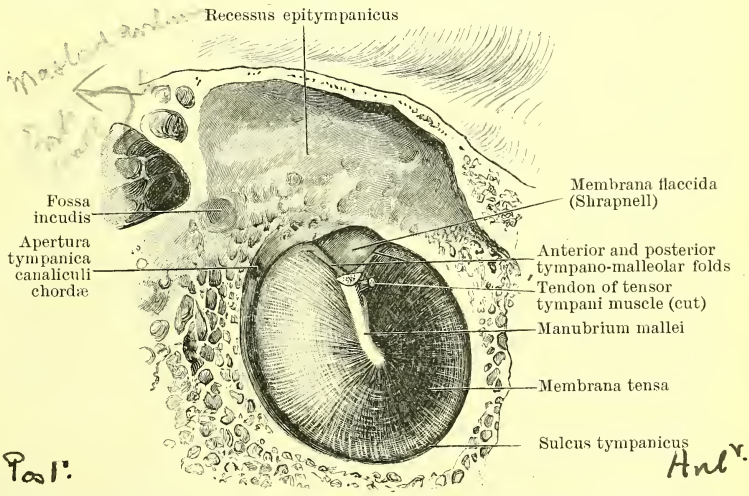


FIG. 584.—LEFT MEMBRANA TYMPANI AND RECESSUS EPITYMPANICUS, viewed from within. The head and neck of the malleus have been removed to show the membrana flaccida and the tympano-malleolar folds. ×3.

The **posterior wall** (paries mastoidea) presents, from above downwards: (1) A rounded or triangular opening, which extends backwards from the recessus epitympanicus and leads into the **mastoid antrum** (Fig. 583); the latter will be again referred to (p. 752). (2) A depression, the **fossa incudis** (Fig. 584), which lodges the extremity of the short process of the incus; this fossa is situated in the postero-inferior part of the recessus epitympanicus. (3) A minute conical bony projection, the **pyramid** or eminentia pyramidalis (Fig. 583), the summit of which is perforated by a round aperture for the passage of the tendon of the stapedius muscle. This aperture is continued downwards and backwards as a canal in front of the Fallopian aqueduct, and frequently opens, by a minute orifice, on the

base of the skull in front of the stylo-mastoid foramen. It communicates with the Fallopian aqueduct by one or two small foramina, through which the vessels and nerve pass to reach the stapedius muscle. A minute spicule of bone often extends from the pyramid to the promontory on the inner wall of the tympanum. (4) A small aperture, the **apertura tympanica canaliculi chordæ** (Fig. 584), which is situated immediately internal to the posterior edge of the membrana tympani, nearly on a level with the upper end of the manubrium mallei, and transmits the chorda tympani nerve. (5) A rounded eminence, the **prominentia styloidea**, is sometimes seen below the last; it is caused by the upward and forward prolongation of the styloid process.

The **anterior wall** (paries carotica) is narrowed in its transverse diameter by the approximation of the outer and inner boundaries of the cavity, and in its vertical diameter by the descent of the roof and ascent of the carotid canal. It presents (Fig. 583) two parallel canals, one above the other, separated by a thin lamella of bone, the **processus cochleariformis** (septum canalis musculo-tubarii). These run forwards on the outer wall of the carotid canal and open in the angle between the petrous and squamous parts of the temporal bone. The higher and smaller of the two is termed the **canal for the tensor tympani muscle** (semicanalis m. tensoris tympani), and lies immediately below the tegmen tympani. It has a diameter of about 2 mm., and extends on to the inner wall of the tympanic cavity above the anterior part of the fenestra ovalis. The lower and larger canal gradually increases in size from before backwards, and forms the **bony part of the Eustachian tube** (semicanalis tubæ auditivæ). It opens on the anterior wall of the tympanic cavity opposite the orifice leading into the mastoid antrum. Below the orifice of the Eustachian tube the anterior part of the tympanic cavity is separated from the ascending portion of the carotid canal by a thin plate of bone in which there are sometimes gaps or deficiencies. It is perforated by a small canal, the carotico-tympanic canal, which transmits the small, deep petrosal nerve from the sympathetic plexus of the carotid artery to the tympanic plexus. The Eustachian tube is described on p. 753.

The **outer wall** (paries membranacea) is formed almost entirely by the membrana tympani (Fig. 584), which closes the inner extremity of the external auditory meatus, and is fixed throughout the greater part of its circumference in a groove, the **sulcus tympanicus**. The bony ring containing this sulcus is deficient superiorly where it exhibits a distinct notch, the **notch of Rivinus**. On a level with the upper edge of the membrane, and in front of the ring of bone in which it is fixed, is the inner end of the **Glaserian fissure**, or remnant of the **fissura petro-tympanica**. This transmits the tympanic branch of the internal maxillary artery, and lodges the processus gracilis and anterior ligament of the malleus. Close to the inner extremity of the fissure is the **canal of Huguier**, or **iter chordæ anterius** through which the chorda tympani nerve leaves the tympanum.

Membrana Tympani.—This is an elliptical disc, its greatest diameter, 9 to 10 mm., being directed from above and behind, downwards and forwards, whilst its least diameter is from 8 to 9 mm. Its antero-inferior portion inclines markedly inwards, and thus the membrane is placed very obliquely, forming an angle of about 55° with the lower and anterior walls of the external auditory meatus; its antero-inferior part is, therefore, most distant from the outer orifice of the meatus. The membrane is said to be more oblique in cretins and deaf mutes, and more perpendicular in musicians.

The circumference of that portion of the membrane which is fixed in the sulcus tympanicus is considerably thickened, and is named the **annulus fibro-cartilagineus**. It is prolonged from the anterior and posterior extremities of the notch of Rivinus to the short process of the malleus in the form of two ligamentous bands, the **anterior** and **posterior malleolar folds** or **ligaments** (plica malleolaris anterior et posterior). The small triangular portion of the membrane (Fig. 584) situated above these folds is thin and lax, and constitutes the **pars flaccida** or membrane of Shrapnell; the main portion of the membrane is, on the other hand, tightly stretched and termed the **pars tensa**. A small orifice, sometimes seen in the pars flaccida, is probably either a pathological condition or has been artificially produced during manipulation. The handle of the malleus is firmly fixed to the inner

surface of the membrana tympani and draws its central portion inwards, rendering its outer aspect concave. The deepest part of this concavity corresponds with the lower extremity of the handle of the malleus, and is named the **umbo membranæ tympanæ** or **navel.**

The membrane tympani consists of three layers: (1) external, integumentary (stratum cutaneum); (2) middle, fibrous (membrana propria); (3) internal, mucous (stratum mucosum).

The **external layer** (stratum cutaneum) is continuous with the integumentary lining of the meatus, and consists of a thin layer of cutis covered by epidermis. The cutis is thickest near the circumference; the epidermis, on the other hand, is thickest near the centre of the membrane.

The **middle layer** (membrana propria) consists of two sets of fibres: (*a*) *external* or *radial* (stratum radiatum), situated immediately under the integument, and radiating from the handle of the malleus to the annulus fibro-cartilagineus; (*b*) *internal* or *circular* (stratum circulare), the fibres of which are numerous near the circumference, but scattered and few in number near the centre of the membrane (Fig. 584). Both radial and circular fibres are absent from the pars flaccida, which is constituted merely by the apposition of the cutaneous and mucous layers. Gruber pointed out that, in addition to the radial and circular fibres, there exists, next the stratum mucosum, a series of *dendritic* or *branched fibres*, which are best developed in the posterior part of the membrane.

The **internal layer** (stratum mucosum) is continuous with the general mucous lining of the tympanum. It is thicker over the upper part of the membrane than near its centre, and is covered by pavement epithelium.

Otoscopic Examination of the Tympanic Membrane (Fig. 585).—The membrane, in the living, is of a "pearl-gray" colour, but may present a reddish or yellowish tinge, depending upon the condition of its mucous lining and on the condition of the cutaneous lining of the meatus; the posterior segment is usually clearer than the anterior. At the antero-superior part, close to its periphery, a whitish point appears as if projecting towards the meatus; this is the short process of the malleus. Passing downwards and backwards from this point to the umbo is a ridge caused by the handle of the malleus, the lower extremity of which appears rounded. Two ridges, corresponding with the tympano-malleolar folds, extend from the short process of the malleus, one forwards and upwards, the other backwards and upwards. Behind, and near the lower extremity of the handle of the malleus, is a reddish or yellowish spot, due to the promontory of the inner tympanic wall shining through. If the membrane be very transparent, the long process of the incus may be visible behind the upper part of the handle of the malleus, and reaching downwards as far as its middle. From the lower end of the handle of the malleus, the "cone of light" or "luminous triangle" extends downwards and forwards, its apex being directed towards the handle; this triangle varies in size in different people. A line prolonging the handle downwards divides the membrane into two parts, while another, drawn at right angles to this through the umbo, will subdivide it into four quadrants, viz. postero-superior, postero-inferior, antero-superior, and antero-inferior; this subdivision is useful in enabling the otologist to localise and describe accurately the seat of lesions in the membrane.

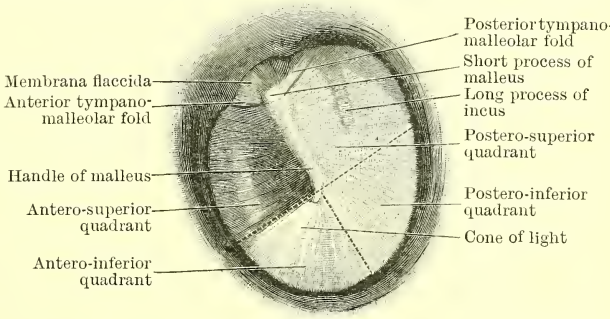


FIG. 585.—LEFT TYMPANIC MEMBRANE (as viewed from the external auditory meatus). ×3.

Vascular and Nervous Supply of the Membrana Tympani.—The **arteries** are arranged in two sets, one on the cutaneous and another on the mucous surface. These anastomose by means of small branches which pierce the membrane, especially near its periphery. The first set is chiefly derived from the deep auricular branch of the internal maxillary, whilst those on the mucous surface are small and proceed from the tympanic branch of the internal maxillary, and from the stylo-mastoid branch of the posterior auricular. The **veins** from the cutaneous surface open into the external jugular; those from the inner surface partly into the venous plexus on the Eustachian tube, and partly into the lateral sinus and veins of the dura mater. The outer surface of the membrane receives its **nerves** from the auriculo-temporal branch of the fifth and from the auricular branch of the vagus; the inner surface, from the nerve of Jacobson (tympanic branch of the glosso-pharyngeal). The **lymphatics**, like the blood-vessels, are arranged in two

sets, cutaneous and mucous, which, however, communicate freely with each other. Kessel has described as lymphatics the spaces between the branches of Gruber's dendritic fibres.

The **inner wall** of the tympanic cavity (paries labyrinthica) is formed by the outer surface of the internal ear or labyrinth (Fig. 583). It presents—(1) a rounded eminence, the **promontory** (promontorium), which is caused by the first coil of the cochlea, and is grooved for the tympanic plexus of nerves. (2) An oval or somewhat reniform opening, the **fenestra ovalis seu vestibuli**, which is situated above and behind the promontory, with its long axis directed from before backwards. It measures 3 mm. in length and $1\frac{1}{2}$ mm. from above downwards, and lies at the bottom of a funnel-shaped recess, the **fossula fenestræ vestibuli**. In the macerated bone it leads into the vestibule of the labyrinth, but is closed in the recent state by the foot of the stapes, surrounded by its **ligamentum annulare**. (3) An elevation, the **prominentia canalis facialis**, which is situated above the fenestra ovalis, in the recessus epitympanicus. This indicates the position of the upper part of the **aqueduct of Fallopius**, which contains the facial nerve and is continued backwards and downwards behind the tympanic cavity, to end at the stylo-mastoid foramen. (4) The **processus cochleariformis**, or septum canalis musculo-tubarii; this process extends backwards, above the anterior end of the fenestra ovalis, where it makes a sharp outward curve, and forms a pulley over which the tendon of the tensor tympani muscle plays. (5) A funnel-shaped recess, the **fossula fenestræ cochleæ**, which is situated behind and below the promontory, and almost hidden by its overhanging edge. It leads forwards, upwards, and inwards to an irregularly oval opening, termed the **fenestra rotunda seu cochleæ**, which in the macerated bone communicates with the cochlea, but in the recent state is closed by a membrane, the **membrana tympani secundaria**. This membrane appears angularly bent along a line joining its antero-inferior two-thirds with the postero-superior third. It consists of three layers: (*a*) *external*, continuous with the mucous lining of the tympanum and containing a network of capillaries; (*b*) *middle*, or substantia propria, the fibres of which radiate chiefly towards the periphery of the membrane —some branched, dendritic fibres are also present; (*c*) *internal*, continuous with the epithelial lining of the labyrinth. (6) Between the fenestra ovalis above and the fossula rotunda below is a small circular depression, the **sinus tympani**, which is perforated by one or two minute foramina for blood-vessels, and indicates the position of the ampullated extremity of the posterior semicircular canal.

Mastoid Antrum and Mastoid Air-cells.

The **mastoid antrum** (antrum mastoideum seu tympanicum) is seen in the temporal bone at birth as a cavity, having a vertical measurement of 7-9 mm. and a transverse of 9-11 mm., and is nearly as large in the newly-born child as in the adult. Roofed in by the tegmen tympani, its floor and inner wall are formed by the petro-mastoid, while externally it is closed by the junction of the thin outer part of the squama with the pars mastoidea. It communicates with the epitympanic recess by a triangular or rounded opening, on the inner wall of which, immediately above and behind the canalis facialis, is a smooth, convex area of bone indicating the position of the ampullated extremities of the superior and external semicircular canals. At birth its outer wall has a thickness of only 1-2 mm., but by the ninth year this has increased to about 10 mm. Coincident with the growth of the mastoid process the mastoid air-cells are developed downwards and backwards as diverticula from the antrum, and present the greatest possible variations in different skulls. They may be large, comparatively few in number, and involve the whole process, in which case the compact bone which surrounds them is extremely thin, and the innermost cells are only separated by a transparent lamella from the lateral sinus—a lamella which, in some instances, is partly deficient. In other cases the cells may be small and numerous, only invading a portion of the process, the remainder consisting of diploëtic tissue. No definite conclusion can be come to as to their condition by external percussion or examination. A solid process is occasionally seen. The air-cells are not limited to the mastoid process, but extend forwards over the roof of the meatus, upwards towards the squama, and inwards towards the

temporo-occipital suture, whilst in a few cases they are seen to invade the pars jugularis of the occipital bone. They, together with the antrum, are lined by thin mucous membrane continuous with that of the tympanic cavity; the deep surface of the mucous membrane is firmly fixed to the periosteum, while its free surface is covered by a layer of flattened, non-ciliated epithelium.

Eustachian Tube.

The **Eustachian tube** (tuba auditiva Eustachii) leads from the tympanic cavity to the naso-pharynx, and transmits air to the former, in order that the pressure on the inner and outer surfaces of the membrana tympani may be equalised; it may also serve to convey mucous secretion away from the tympanic cavity. Its outer extremity, the **ostium tympanicum tubæ auditivæ** (Fig. 583), opens into the anterior part of the tympanic cavity below the canal for the tensor tympani muscle. Directed downwards and inwards, the tube ends on the upper part of the naso-pharynx by a wide orifice, the **ostium pharyngeum tubæ auditivæ** (Fig. 555). It measures about an inch and a half (36 mm.) in length, and forms with the horizontal plane an angle of 30° to 40°, with the sagittal plane an angle of about 45°, and with the bony part of the external meatus one of 135° to 140°. It consists of two portions: (*a*) an antero-internal, fibro-cartilaginous part, the **pars cartilaginea tubæ auditivæ**, having a length of about one inch; and (*b*) a postero-external, osseous part, the **pars ossea tubæ auditivæ**, measuring half an inch in length. The two portions are not in the same plane, the cartilaginous part inclining downwards a little more than the osseous portion, and forming with it a wide angle. Its lumen is widest at the ostium pharyngeum, narrowest at the junction of the bony and cartilaginous portions, forming here the **isthmus**, and again expanding towards the tympanic cavity; hence it presents, on longitudinal section, somewhat the appearance of an hour-glass. The pars ossea occupies the angle between the squamous and petrous parts of the temporal bone, and is separated by the processus cochleariformis from the canal containing the tensor tympani muscle, whilst immediately to its inner side is the carotid canal. The pars cartilaginea consists partly of cartilage and partly of fibrous membrane. The cartilage (cartilago tubæ auditivæ) presents the form of an elongated triangular plate, of which the apex is firmly attached to the inner end of the pars ossea, while the base is free, and forms a projection on the upper and posterior aspects of the pharyngeal orifice. The upper edge of this cartilaginous plate is bent outwards in the form of a hook, and so produces a furrow open below and externally, the furrow being converted into a complete canal by the fibrous part of the tube. On transverse section (Fig. 586) the cartilage presents two laminæ continuous with each other superiorly: (*a*) *lamina medialis*, broad and thick; and (*b*) *lamina lateralis*, thin and hook-shaped. At the ostium pharyngeum the lamina medialis forms the entire inner wall of the tube, but it gradually diminishes in breadth on approaching the isthmus tubæ. Fissures are often seen in the cartilage; sometimes it is completely separated into several pieces, or accessory islands may be observed in the roof, floor, or membranous part.

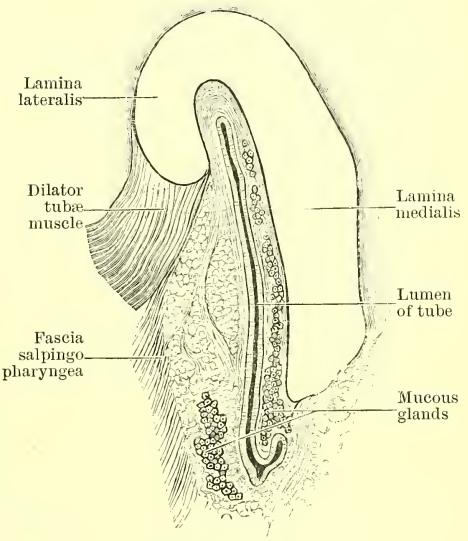


Fig. 586.—Transverse Section of the Cartilaginous Part of the Eustachian Tube.

The upper and inner aspects of the cartilage are firmly fixed to the base of the skull, where it lies in a groove, the **sulcus tubæ auditivæ**, situated between the great wing of the sphenoid and the petrous-temporal. Extending forwards on to the

root of the pterygoid process this sulcus ends at a projection, the **processus tubarius**, on the middle of the internal pterygoid plate. The tensor palati muscle lies to the outer side of the tube and receives some fibres of origin from its lamina lateralis; these fibres constitute the **dilator tubæ muscle** of Rüdinger. To the inner side of the cartilage are found the levator palati and the mucous membrane of the pharynx. The **membranous part** (lamina membranacea) consists of a strong fibrous membrane, stretching between the two edges of the cartilage, and so completing the under and outer parts of the canal. Thin above, it becomes thickened below and forms the **fascia salpingo-pharyngea** of Tröltsch, which gives origin to some of the fibres of the tensor palati muscle. Between this fascia and the mucous lining of the tube is a layer of adipose tissue.

The **pharyngeal orifice** of the Eustachian tube (ostium pharyngeum tubæ), triangular or oval in shape, is situated on the lateral wall of the naso-pharynx, the centre of the opening being on a level with the posterior end of the inferior turbinated bone. It is bounded above and behind by a pad or cushion produced by the inner end of the cartilage, which here abuts against the mucous membrane. The posterior part of this cushion is very prominent and forms the anterior boundary of the **fossa of Rosenmüller.** Prolonged downwards from it is an elevation of the mucous membrane, termed the **plica salpingo-pharyngea**, which covers the small salpingo-pharyngeus muscle. From the upper part of the cushion an indistinct fold, the **plica salpingo-palatina**, extends to the palate.

The mucous lining of the tube is continuous behind with that of the tympanic cavity, and in front with that of the naso-pharynx. It is thin in the pars ossea, contains few, if any, mucous glands, and is firmly fixed to the bony wall; whilst in the pars cartilaginea it is loose and thrown into longitudinal folds. Numerous mucous glands open into the tube near its pharyngeal orifice, and here also there exists a considerable amount of adenoid tissue, which constitutes the "tube-tonsil" of Gerlach. This adenoid tissue is continuous with that of the naso-pharynx, and, like it, is especially well developed in children. The lumen of the tube is lined with ciliated columnar epithelium.

The tube is opened, during deglutition, by the dilator tubæ and salpingo-pharyngeus muscles. The former springs superiorly from the cartilaginous hook of the tube, and blends inferiorly with the tensor palati. When the dilator tubæ contracts, the cartilaginous hook and membranous part of the tube are drawn outwards and forwards. Some anatomists are inclined to the view that the entire tensor palati acts chiefly as a dilator of the tube, and Rüdinger has named it the abductor tubæ. The salpingo-pharyngeus muscle draws downwards and backwards the inner cartilaginous plate, increasing the angle between it and the outer plate. Some difference of opinion exists as to the precise action of the levator palati; probably it assists in opening the tube.

The Eustachian tube receives its blood-supply from the ascending pharyngeal artery and from the middle meningeal and Vidian branches of the internal maxillary artery. Its veins form a network which opens into the pterygoid venous plexus. The sensory nerves of the tube are derived from the tympanic plexus and from the pharyngeal branches of the second division of the fifth cranial nerve.

The tube of the child differs considerably from that of the adult; its lumen is relatively wider, its direction more horizontal, and its pars ossea relatively shorter. Kunkel states that its pharyngeal orifice is below the level of the hard palate in the fœtus; at birth it is on the same level as the palate, whilst at the fourth year it is 3 to 4 mm., and in the adult 10 mm., above it. The pharyngeal orifice forms a narrow fissure, and its cartilage projects less towards the middle line.

Tympanic Ossicles.

The **tympanic ossicles** (ossicula auditus) form an articulated column connecting the outer with the inner wall of the tympanic cavity, and are named, from without inwards, the malleus or hammer, the incus or anvil, and the stapes or stirrup. The first is attached to the inner surface of the membrana tympani; the last is fixed within the circumference of the oval fenestra.

The **malleus** (Fig. 587, B, D), the largest of the three ossicles, has a length of 8 to 9 mm., and consists of a head (capitulum mallei), a neck (collum mallei), and a

handle (manubrium mallei), together with two processes, viz.: (*a*) processus longus seu anterior, (*b*) processus brevis seu lateralis. The head and neck are situated in the epitympanic recess; the processus brevis and manubrium are fixed to the inner surface of the membrana tympani; whilst the processus longus is directed forwards towards the Glaserian fissure, to which, in the adult, it is connected by ligamentous

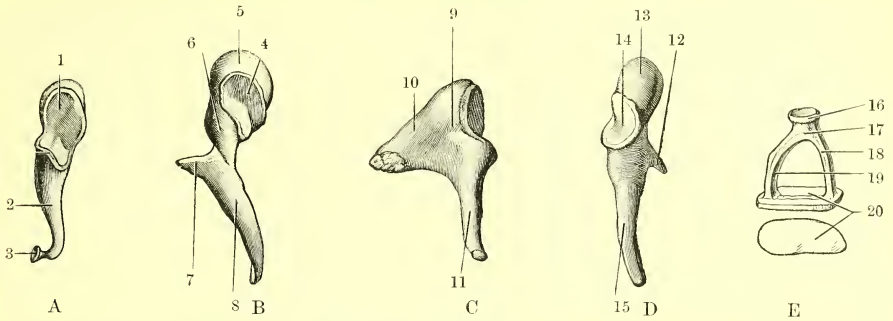


FIG. 587.—TYMPANIC OSSICLES OF LEFT EAR (enlarged about three times).

A, Incus, seen from the front; B, Malleus, viewed from behind; C, Incus, and D, Malleus, seen from inner aspect; E, Stapes.

1. Body of incus, with articular surface for head of malleus.
2. Processus longus.
3. Processus lenticularis.
4. Articular surface for incus.
5. Head.
6. Neck.
7. Processus brevis.
8. Manubrium.
9. Body.
10. Short process.
11. Long process.
12. Processus longus.
13. Head.
14. Facet for incus.
15. Manubrium.
16. Head.
17. Neck.
18. Crus anterius.
19. Crus posterius.
20. Foot-plate.

fibres. The **head**, somewhat rounded, is smooth and convex above and in front, and presents, on its posterior aspect, a facet for articulation with the body of the incus. This facet is directed obliquely downwards and inwards, and reaches slightly on to its mesial surface. More or less elliptical in form, it is constricted near the middle so as to resemble, somewhat, the figure 8; an oblique ridge, corresponding with the constriction, divides the facet into two parts—an upper and larger, directed back-

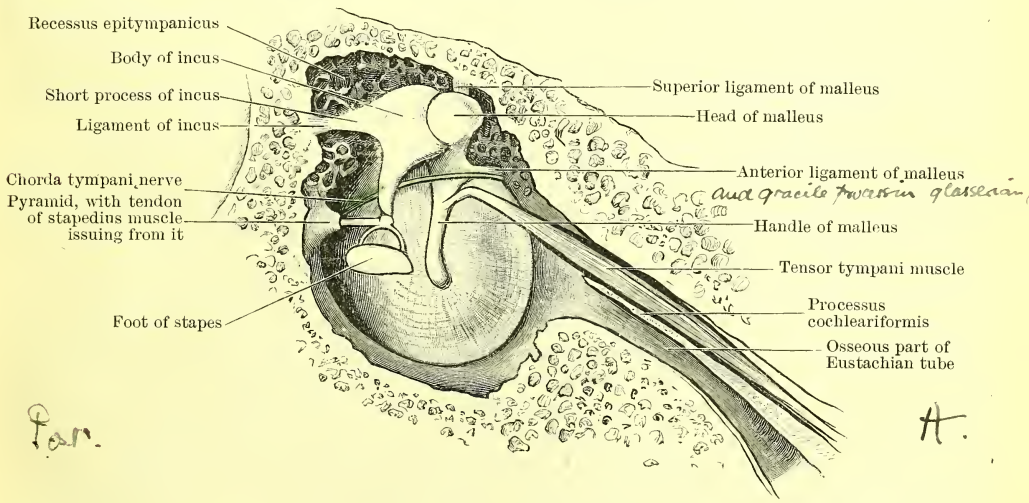


FIG. 588.—LEFT MEMBRANA TYMPANI AND CHAIN OF TYMPANIC OSSICLES (seen from inner aspect). × 3.

wards, and a lower and lesser, directed inwards. Opposite the lower part of the constriction the inferior edge of the facet is very prominent, and is continued upwards into the oblique ridge just referred to; it forms a tooth-like process, the **spur** or **cog-tooth** of the malleus. On the back of the head, below this spur, is an oblique crest, the **crista mallei**, to which is attached the external ligament of the malleus. The **neck** is the slightly constricted portion immediately below the head. Flattened from before backwards, its outer surface is directed towards the membrana flaccida,

whilst its inner is crossed by the chorda tympani nerve. The **handle** is directed downwards, inwards, and backwards from the neck, forming with the long axis of the head an angle, opening inwards, of 126° to 150°. Its upper part is flattened from before backwards, but towards the lower end it is twisted on itself, so that its surfaces look outwards and inwards; moreover, the lower end is slightly curved, the concavity being directed forwards and outwards. It is fixed, along its entire length, to the membrana propria of the tympanic membrane by its periosteum and by a layer of cartilage (Gruber). This latter intervenes between the handle and the membrane, and must be regarded as a residue of that stage of development when the entire malleus was cartilaginous. On the inner aspect of the handle, near its upper extremity, a slight projection for the attachment of the tendon of the tensor tympani muscle may be seen. The **long process** is a slender spicule springing from the fore-part of the neck and directed forwards towards the Glaserian fissure. In the fœtus it constitutes the longest process of the malleus and is directly continuous with Meckel's cartilage. In the adult it usually assumes the form of a small projection, since its anterior part is represented merely by fibrous tissue. The **short process** may be looked upon as the upper extremity of the handle projected outwards; it is fixed to the upper part of the membrana tympani by the cartilaginous layer already referred to, and to the extremities of the notch of Rivinus by the anterior and posterior malleolar folds.

The **incus** (Fig. 587, A, C) is best likened to a bicuspid tooth with widely divergent fangs. It consists of a body (corpus incudis), a long process (crus longum), and a short process (crus breve); the two processes form with each other an angle of 90° to 100°. The body and short process are situated in the epitympanic recess. The **body** presents a more or less saddle-shaped surface for articulation with the head of the malleus. This surface is directed forwards, and its lower part is hollowed out for the accommodation of the cog-tooth of the malleus. In front of this hollow it is prominent and spur-like. The **short process** is thick, triangular in shape, and projects horizontally backwards; its conical extremity, covered with cartilage, articulates with the fossa incudis in the postero-inferior part of the epitympanic recess. The **long process** projects, almost perpendicularly, downwards from the body into the tympanic cavity, where it lies parallel with, but $1\frac{1}{4}$ mm. behind and internal to, the handle of the malleus. Its lower end is bent inwards and narrowed to form a short neck, on the inner extremity of which is a small knob of bone, the **processus lenticularis**, for articulation with the head of the stapes. Until the sixth month of fœtal life this process exists as a separate ossicle, termed the **os orbiculare**.

The **stapes** (Fig. 587, E) presents a head (capitulum stapedis), a neck (collum stapedis), two crura (crus anterius et posterius), and a base or foot-plate (basis stapedis). The **head**, directed outwards, is concave externally for articulation with the processus lenticularis of the incus. The **neck** is the slightly constricted part immediately internal to the head, and from it the two crura spring; the tendon of the stapedius muscle is inserted into the posterior aspect of the neck. The anterior crus is shorter and less curved than the posterior. Diverging from each other, the crura are directed inwards and are attached—one near the anterior, the other near the posterior end of the foot-plate. The **foot-plate** almost completely fills the oval fenestra, and, like it, is somewhat oval or reniform, its anterior end being the more pointed. In the recent condition a membrane fills the arch formed by the crura and the foot-plate, the crura being grooved for its reception. In the child the crura of the stapes are less curved than in the adult, and the opening bounded by them and the foot-plate is nearly triangular.

Articulations of the Tympanic Ossicles.—The joint between the head of the malleus and the body of the incus (articulatio incudomalleolaris) is diarthrodial, and may be described as one of reciprocal reception. It is surrounded by a capsular ligament, from the inner surface of which a wedge-shaped meniscus projects into the joint cavity and incompletely divides it. The articulation of the processus lenticularis and the capitulum stapedis (articulatio incudostapedia) is of the nature of an enarthrosis and is surrounded by a capsular ligament. An interarticular cartilage has been described as occurring in this joint, while some observers deny the

presence of a synovial cavity and regard the articulation as a syndesmosis, the articular surfaces being held together merely by fibrous tissue.

Ligaments binding the Ossicles to the Walls of the Tympanic Cavity (lig. ossiculorum auditus).—The malleus is attached to the walls of the tympanum by three ligaments (Fig. 588), viz. anterior, superior, and external. The **anterior ligament** (lig. mallei anterius) consists of two portions: (*a*) the *band of Meckel*, which is attached to the base of the processus longus, and passes forwards through the Glaserian fissure to reach the spine of the sphenoid; it represents the remnant of a portion of Meckel's cartilage, and was formerly described as the laxator tympani muscle; (*b*) a firm bundle of fibres, the *lig. mallei anterius of Helmholtz*, which extends from the spina tympanica posterior at the anterior boundary of the notch of Rivinus to the anterior aspect of the malleus, above the base of the processus longus. The **superior ligament** (lig. mallei superius) extends, almost vertically, from the head of the malleus to the roof of the epitympanic recess. The **external ligament** (lig. mallei laterale) is short and fan-shaped; its fibres converge from the posterior half of the notch of Rivinus to the crista mallei. The posterior part of this ligament is strong and constitutes the *ligamentum mallei posticum of Helmholtz*. It forms, together with the ligamentum mallei anterius, the axis around which the malleus rotates, and the two constitute what Helmholtz has termed the "**axis-ligament**" of the malleus.

The posterior extremity of the crus breve of the incus is tipped with cartilage and fixed by means of a ligament, the **ligamentum incudis posterius** (Fig. 588), to the fossa incudis. Some observers describe this as a diarthrodial joint. A superior ligament, the **ligamentum incudis superius**, is sometimes present, but consists mainly of a fold of mucous membrane. The vestibular surface and the circumference of the foot of the stapes are covered by hyaline cartilage, and a similar layer lines the opening of the fenestra ovalis; that encircling the base of the stapes is joined to that which lines the fenestra by a dense ring of elastic fibres, named the **ligamentum annulare baseos stapedis**. The posterior fibres of this annular ligament are thicker and shorter than the anterior, and thus the anterior end of the foot-plate is free to make greater excursions, during the movements of the bone, than the posterior.

Development of the Tympanic Ossicles.—It is generally maintained that the malleus and incus are developed from the upper end of Meckel's cartilage, and that the stapes arises from the mesoblast in the region of the fenestra ovalis where it is developed around a small artery, the stapedial artery, which atrophies in man, but persists in many mammals. On the other hand, Gadow (*Phil. Trans.*, London, vol. clxxix.) says "the whole system of the one to four elements of the middle ear, which have all the same function, is to be looked upon as *one* organ, of *one* common origin, viz. a modification of the hyomandibula, the proximal paramere of the second visceral arch."

Muscles of the Tympanic Cavity.—These are two in number, viz. m. tensor tympani and m. stapedius.

The **m. tensor tympani** is the larger, and takes origin from the roof of the cartilaginous part of the Eustachian tube and from the adjacent part of the great wing of the sphenoid. It also receives some fibres from the bony canal in which it lies, and ends in a tendon which bends outwards, nearly at a right angle to the belly of the muscle, round the pulley-like, posterior extremity of the processus cochleariformis. Passing across the cavity of the tympanum this tendon is inserted into the inner edge and anterior surface of the manubrium mallei, near its upper end. When the muscle contracts it draws inwards the handle of the malleus, and so renders tense the membrana tympani; it probably also slightly rotates the malleus around its long axis. It receives its nerve from the motor division of the fifth cranial nerve through the otic ganglion.

The **m. stapedius** arises within the pyramid, and from the canal which prolongs the hollow of the pyramid downwards. Its tendon emerges from the apex of the pyramid and is inserted into the posterior surface of the neck of the stapes. On contraction it draws back the head of the stapes, and so tilts the anterior end of the foot-plate outwards towards the tympanic cavity and the posterior end inwards

towards the labyrinth, thus rendering tense the ligamentum annulare—the outward movement of the anterior end of the foot-plate being greater than the inward movement of its posterior end. The muscle is supplied by the facial nerve.

Movements of the Tympanic Ossicles.—The manubrium mallei follows all the movements of the membrana tympani, while the malleus and incus move together around an axis extending forwards through the short process of the incus and the anterior ligament of the malleus. When the membrana tympani moves inwards it carries with it the handle of the malleus, and the incus, moving inwards at the same time, forces the foot of the stapes towards the labyrinth. This inward movement is communicated to the fluid (perilymph) in the labyrinth, and causes an outward bulging of the secondary tympanic membrane, which closes the fenestra rotunda. These movements are reversed when the membrana tympani is relaxed, unless the outward movement of the membrane be excessive. In such a condition the incus does not follow the full outward movement of the malleus, but merely glides on this bone at the incudo-malleolar joint, and thus the forcible dragging of the foot of the stapes out of the fenestra ovalis is prevented. The cog-tooth arrangement, already described, on the head of the malleus and body of the incus, causes the incudo-malleolar joint to become locked during the inward movements of the handle of the malleus, the joint becoming unlocked during its outward movements.

Mucous Lining of the Tympanic Cavity (tunica mucosa tympanica).—This is continuous, through the Eustachian tube, with that of the naso-pharynx; it also extends backwards and lines the mastoid antrum and air-cells. Thin, transparent, and closely united with the subjacent periosteum, it covers the inner aspect of the membrana tympani and is reflected over the ossicles and their ligaments. It also supplies sheaths for the tendons of the tensor tympani and stapedius muscles, and forms the following **mucous folds**, viz.: (*a*) one from the roof of the epitympanic recess to the head of the malleus and body of the incus; (*b*) one enveloping the chorda tympani nerve and long process of the incus; (*c*) two extending from the short process of the malleus—one to the anterior, the other to the posterior margin of the notch of Rivinus. A recess, the **pouch of Prussak**, is situated between the membrana flaccida and the neck of the malleus. Communicating behind with the tympanic cavity, this pouch may serve as a reservoir to confine pus or other fluid, since its opening into the tympanum is above the level of its floor, a condition analogous to the opening from the antrum of Highmore into the nasal cavity. The fold of mucous membrane which extends downwards to envelop the chorda tympani nerve gives rise to two pouches, one in front of, and the other behind, the handle of the malleus; these are named the **anterior** and **posterior recesses of Tröltsch.** The epithelium which lines the mucous membrane is flattened over the membrana tympani, promontory, and ossicles, but ciliated and columnar over the greater portion of the rest of the cavity.

The chorda tympani branch of the facial nerve passes from behind, upwards, and forwards through the tympanic cavity. Its course is described on p. 687.

Vessels and Nerves of the Tympanic Cavity.—The **arteries** which supply the tympanic cavity are: (1) The tympanic artery, a branch of internal maxillary, which reaches the cavity by way of the Glaserian fissure. (2) The stylo-mastoid branch of posterior auricular, which passes through the stylo-mastoid foramen and aqueduct of Fallopius; it supplies branches to the mastoid antrum and air-cells, to the stapedius muscle, to the floor and inner wall of the tympanic cavity, and forms an anastomotic circle, around the membrana tympani, with the tympanic artery. (3) The middle meningeal artery sends a branch to the tensor tympani muscle, and, after entering the skull, gives off its petrosal artery, which is conducted to the tympanum along the hiatus Fallopii; some twigs from the posterior division of the middle meningeal reach the antrum and epitympanic recess through the petro-squamous fissure. (4) The internal carotid artery, in its passage through the canal in the temporal bone, gives off one or two tympanic twigs, while (5) a branch from the ascending pharyngeal accompanies the nerve of Jacobson. The **veins** drain their contents into the pterygoid plexus, the middle meningeal vein, and superior petrosal sinus. The **nerves** which supply the muscles of the tympanic cavity have already been referred to (pp. 757, 758). The mucous membrane receives its nerves from the tympanic plexus, which is described on p. 690.

Early Condition of Tympanic Cavity.—During the greater part of intrauterine existence the tympanic cavity is almost completely filled by a soft, reddish, jelly-like embryonic tissue. The narrow, slit-like space is lined by epithelium, which is ciliated over the promontory, but squamous elsewhere. Towards the end of fœtal life the gelatinous tissue becomes thinned and the cavity correspondingly enlarged. At birth it is filled with fluid which becomes absorbed, coincident with the passage of air from the naso-pharynx through the Eustachian tube.

INTERNAL EAR.

The innermost, and, at the same time, the essential part of the organ of hearing is situated in the substance of the petrous-temporal bone, and consists of two sets of structures, viz.: (1) a series of cavities hollowed out of the bone and constituting the **bony labyrinth** (labyrinthus osseus); these cavities are continuous with each

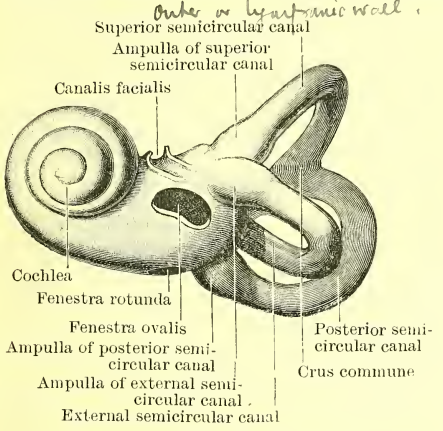


FIG. 589.—LEFT BONY LABYRINTH (viewed from the outer aspect).

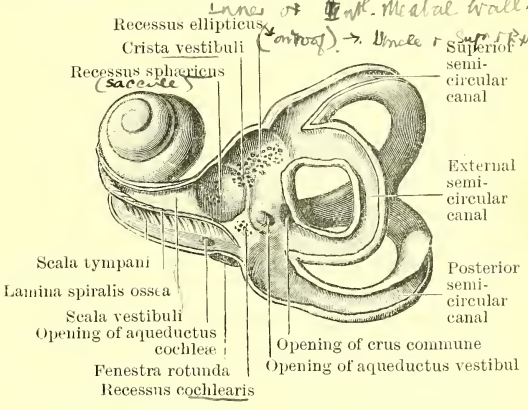


FIG. 590.—INTERIOR OF LEFT BONY LABYRINTH (viewed from outer aspect).

other, and are named from before backwards the **cochlea**, **vestibule**, and **semicircular canals** (Figs. 589, 590); (2) a complex arrangement of membranous channels (Fig. 592), situated within, but not nearly filling, the bony labyrinth and forming the **membranous labyrinth** (labyrinthus membranaceus). These channels are named the **ductus cochlearis**, **utricle, saccule**, and **membranous semicircular canals**; the utricle and saccule are lodged within the bony vestibule.

OSSEOUS LABYRINTH.

Vestibule.—The vestibule forms the central portion of the osseous labyrinth, and communicates behind with the semicircular canals and in front with the cochlea. It is somewhat ovoid in shape, its long axis being directed forwards and outwards. It measures about 6 mm. antero-posteriorly, 4-5 mm. from roof to floor, and about 3 mm. from without inwards. Its outer wall is directed towards the tympanic cavity, and in it is seen the fenestra ovalis, which, in the recent state, is closed by the foot of the stapes. Its inner wall corresponds with the bottom of the internal auditory meatus, and presents, at its antero-inferior part, a rounded depression, the **recessus sphæricus**, which lodges the saccule. This recess is perforated by some twelve or fifteen small foramina, which constitute the **macula cribrosa media**, and transmit the filaments of the auditory nerve for the supply of the saccule. The recessus sphæricus is limited above and behind by an oblique ridge, the **crista vestibuli**, the anterior extremity of which is triangular in shape and named the **pyramid** (pyramis vestibuli). Posteriorly this crista divides into two limbs, between which is a small depression, the **recessus cochlearis** of Reichert, perforated by some eight small foramina, which give passage to the nervous filaments for the supply of the posterior extremity of the ductus cochlearis. Above and behind the crista vestibuli, in the roof and inner wall of the vestibule, is an oval depression, the **recessus ellipticus**, which lodges the utricle. The pyramid and adjacent part of the recessus ellipticus are perforated by some 25-30 small apertures, which constitute the **macula cribrosa superior seu major**. The foramina in the pyramid transmit the nerves to the utricle; those in the recessus, the nerves to the ampullary ends of the superior and external semicircular canals. Behind and below the recessus ellipticus is a furrow, gradually deepening to form a canal, the **aqueductus vestibuli**, which passes backwards through the petrous bone, and opens, as a slit-like fissure, about midway between the internal auditory meatus and the groove for the lateral sinus. This

aqueduct measures 8-10 mm. in length, and gives passage to the ductus endolymphaticus and a small vein. The posterior part of the vestibule receives the five rounded apertures of the bony semicircular canals; its anterior part leads, by an elliptical opening, into the scala vestibuli of the cochlea. This opening is bounded inferiorly by a thin osseous lamella, the **lamina spiralis ossea**, which springs from the floor of the vestibule immediately to the outer side of the recessus sphæricus, and forms, in the cochlea, the bony part of the septum between the scala tympani below and the scala vestibuli above. From the anterior part of the floor of the vestibule a narrow cleft, the **fissura vestibuli**, extends forwards into the bony canal of the cochlea. It is bounded internally by the lamina spiralis ossea just referred to, and externally by a second, smaller lamina, the **lamina spiralis secundaria**, which projects inwards from the outer wall of the cochlea. These two lamina are continuous with each other around the posterior extremity of the fissure.

Semicircular Canals (canales semicirculares ossei).—The semicircular canals (Figs. 589, 590), three in number, are situated above and behind the vestibule. They are distinguished from each other by their position, and are named superior, posterior, and external. They open into the vestibule by five apertures, since the inner extremity of the superior and the upper extremity of the posterior join to form a common canal or crus commune. Differing slightly in length, each forms about two-thirds of a circle, one extremity of which is dilated and termed the ampulla (ampulla ossea). Somewhat compressed laterally, their greatest internal diameter is from 1 to 1·5 mm., whilst the diameter of the ampulla is about 2 mm.

The **superior semicircular canal** (canalis semicircularis superior), 15-20 mm. in length, is vertical and placed transversely to the long axis of the petrous bone. Its convexity is directed upwards, and its position is indicated on the anterior surface of the petrous-temporal by an eminence. Its ampullated end (ampulla ossea superior) is anterior and external, and opens into the vestibule immediately above that of the external canal. Its opposite extremity joins the non-ampullated end of the posterior canal to form the **crus commune**, which is about 4 mm. in length, and opens into the upper and inner part of the vestibule. The **posterior semicircular canal** (canalis semicircularis posterior) is the longest of the three and measures from 18-22 mm. Its ampullary end (ampulla ossea posterior) is placed inferiorly, and opens into the lower and back part of the vestibule, where may be seen some six or eight small apertures, forming the **macula cribrosa inferior**, for the transmission of the nerves to this ampulla. Its upper extremity ends in the crus commune. The **external canal** (canalis semicircularis lateralis) is the shortest. It measures from 12 to 15 mm., and arches nearly horizontally outwards. Of its two extremities the external is ampullated (ampulla ossea lateralis), and opens into the vestibule immediately above the fenestra ovalis and in close relationship to the ampullary end of the superior canal.

Although the three canals are generally regarded as opening into the vestibule by five orifices, some observers incline to the view that the ampullary ends of the superior and external canals form a common orifice, and that, consequently, there are only four openings for the three canals. Crum Brown (*Journ. Anat. and Physiol.*, London, vol. viii.) pointed out "that the exterior canal of one ear is very nearly in the same plane as that of the other; while the superior canal of one ear is nearly parallel to the posterior canal of the other."

Cochlea.[1]—When freed from its surroundings the cochlea assumes the form of a short cone (Fig. 591); the central part of its **base** (basis cochleæ) corresponds with the bottom of the internal auditory meatus, whilst its apex or **cupola** is directed forwards and outwards, and comes into close relation with the canal for the tensor tympani muscle. It measures about 9 mm. across the base and about 5 mm. from base to apex, and consists of a spirally arranged tube, which forms from $2\frac{1}{2}$ to $2\frac{3}{4}$ coils around a central pillar termed the **modiolus**. The length of the tube is from 28 to 30 mm., and its diameter, near the base of the cochlea, 2 mm. Its coils are distinguished by the terms basal, central, and apical; the first, or basal coil, gives rise to the promontory on the inner wall of the tympanum.

[1] In the following description the cochlea is supposed to be placed on its base.

The modiolus is about 3 mm. in height, and diminishes rapidly in diameter from base to apex, while its tapered extremity fails to reach the cupola by a distance of 1 mm. Its **base** (basis modioli) corresponds with the **area cochleæ** on the fundus of the internal auditory meatus, and exhibits the **tractus spiralis foraminosus**, which transmits the nerves for the basal and central coils of the cochlea and the **foramen centrale**, which gives passage to the nerves for the apical coil. The foramina of the tractus spiralis foraminosus traverse the modiolus, at first parallel to its long axis, but, after a varying distance, they bend outwards to reach the attached edge of the lamina spiralis ossea, where they become expanded and form by their apposition a spiral canal, the **canalis spiralis modioli of Rosenthal**, which lodges the **ganglion of Corti**, or **ganglion spirale cochleæ**. From this spiral canal numerous small foramina, for the transmission of vessels and nerves, pass outwards to the free edge of the lamina spiralis. The **lamina spiralis ossea**, a thin, flat shelf of bone, winds round the modiolus like the thread of a screw, and, projecting about half-way into the cochlear tube, incompletely divides it into two passages, of which the upper is named the **scala vestibuli**; the lower, the **scala tympani**. The lamina spiralis ossea commences at the floor of the vestibule, near the fenestra rotunda, and ends close to the apex of the cochlea in a sickle-shaped process, the **hamulus**, which assists to form an

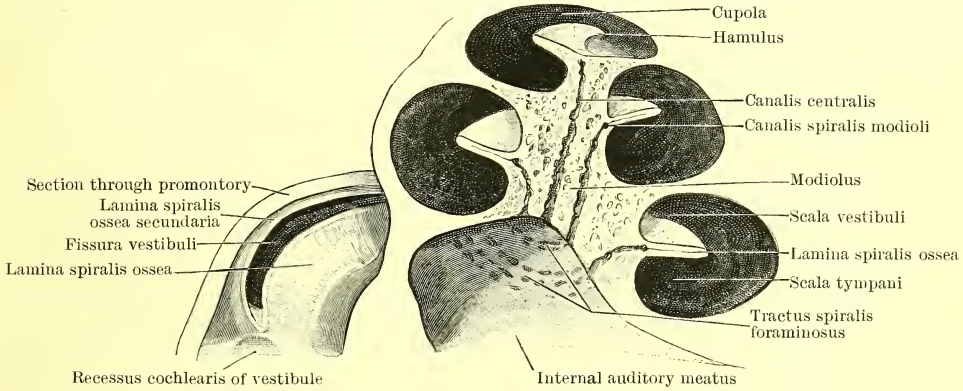


Fig. 591.—Section of Bony Cochlea.

aperture named the **helicotrema**. In the basil coil the upper surface of the spiral lamina forms almost a right angle with the modiolus, but the angle becomes more and more acute on ascending the tube. In the lower half of the basil coil a second smaller bony plate, the **lamina spiralis secundaria**, projects inwards from the outer wall of the cochlea towards the lamina spiralis ossea, without, however, reaching it. If viewed from the vestibule the slit-like fissura vestibuli, already referred to (p. 760), is seen between the two osseous spiral laminæ. A membrane, the **membrana basilaris**, stretches from the free edge of the lamina spiralis ossea to the outer wall of the cochlea, and completes the septum between the scala vestibuli and scala tympani, but the two scalæ communicate with each other through the opening of the helicotrema at the apex of the cochlea. The scala tympani begins at the fenestra rotunda, through which, in the macerated bone, it communicates with the tympanic cavity; in the recent condition the fenestra is closed by the secondary tympanic membrane (*vide* p. 752). At the commencement of the scala tympani a crest, termed the **crista semilunaris**, stretches from the attached margin of the lamina spiralis ossea towards the orifice of the fenestra rotunda. Close to this crest is seen the inner orifice of the **aqueductus cochleæ**, a canal measuring from 10 to 12 mm. in length, and opening on the under aspect of the petrous bone internal to the fossa jugularis. Through it there is established a communication between the scala tympani and the subarachnoid space, and through it, also, a small vein passes to join the inferior petrosal sinus. The scala vestibuli, the higher of the two passages, begins in the vestibule; its diameter in the basal coil is less than that of the scala tympani, but in the upper coils it exceeds that of the latter.

Internal Auditory Meatus.—It is convenient, at this stage, to study the

fundus of the internal auditory meatus, which has been referred to as forming the inner wall of the vestibule and the base of the modiolus. It is divided by a transverse ridge, the **crista transversa**, into two parts—an upper or **fossula superior** and a lower or **fossula inferior.** The anterior part of the fossula superior is termed the **area facialis** and exhibits a single large opening, the commencement of the aqueduct of Fallopius, for the transmission of the facial nerve. Its posterior part is named the **area vestibularis superior,** and is perforated by the nerves for utricle and ampullæ of the superior and external semicircular canals. The anterior part of the fossula inferior is termed the **area cochleæ,** and consists of the **canalis centralis** and the surrounding **tractus spiralis foraminosus,** for the passage of the nerves to the cochlea. Behind the area cochleæ, and separated from it by a ridge, is the **area vestibularis inferior,** which transmits the nerves to the saccule, whilst at the posterior part of the fossula inferior is seen a single foramen, the **foramen singulare,** which gives passage to the nerves for the ampulla of the posterior semicircular canal.

MEMBRANOUS LABYRINTH.

The **membranous labyrinth** (labyrinthus membranaceus) assumes, more or less closely (Fig. 592), the form of the bony labyrinth in which it is situated, but does not nearly fill it. It contains a fluid termed **endolymph,** while the interval between it and the bony labyrinth is named the **perilymphatic space,** and is occupied by a fluid termed **perilymph.** The perilymphatic space in the vestibule measures about 3 mm. from without inwards, and about 3·5 mm. from before backwards. It is continuous behind with the perilymphatic space of the semicircular canals, and opens in front into the scala vestibuli. At the apex of the cochlea it is continuous through the helicotrema with the scala tympani, which is shut off from the tympanum by the secondary tympanic membrane. It is also prolonged into the aqueductus cochleæ, at the extremity of which it communicates with the subarachnoid space. The membranous semicircular canals and the membranous canal of the cochlea follow the course of their bony tubes and lie along the inner aspect of their outer walls. The bony vestibule, on the other hand, contains two chief membranous structures, the **utricle** and **saccule.** The former receives the extremities of the membranous semicircular canals, whilst the latter communicates with the membranous canal of the cochlea. Moreover, the cavities of the utricle and saccule are indirectly connected, and thus all parts of the membranous labyrinth communicate with each other, and the contained endolymph is free to move from one portion to another. The vestibule, also, contains the ductus endolymphaticus and the commencement of the ductus cochlearis.

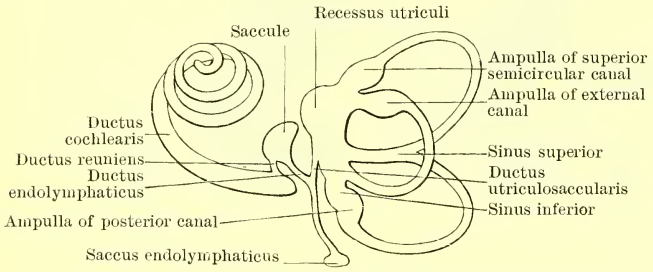


FIG. 592.—DIAGRAMMATIC REPRESENTATION OF THE DIFFERENT PARTS ON THE MEMBRANOUS LABYRINTH.

The **utricle** (utriculus), the larger of the two sacs (Fig. 592), occupies the postero-superior portion of the bony vestibule. Its highest part, or **recessus utriculi,** lies in the recessus ellipticus and receives the ampullæ of the superior and external membranous semicircular canals. Its central part receives on its lateral aspect the non-ampullated end of the external canal, and is prolonged upwards and backwards as the **sinus superior,** into which the crus commune of the superior and posterior membranous canals open. The ampulla of the posterior membranous canal opens into its lower and inner part, or **sinus inferior.** The floor and anterior wall of the recessus utriculi are thickened to form the **macula acustica utriculi,** to which are distributed the utricular fibres of the auditory nerve. Whitish in colour, and of an oval or nearly rhombic shape, this macula measures 3 mm. in length and 2·3 mm. in its greatest breadth.

The **saccule** (sacculus) occupies the recessus sphæricus, in the lower and fore-part of the vestibule (Fig. 590). Smaller than the utricle, it is of an oval shape and measures 3 mm. in its longest, and about 2 mm. in its shortest diameter. It presents anteriorly an oval, whitish thickening, the **macula acustica sacculi**. This has a breadth of about 1·5 mm., and to it are distributed the saccular fibres of the auditory nerve. The superior extremity of the saccule is directed upwards and backwards, and forms the **sinus utricularis sacculi**, which abuts against, but does not fuse with, the wall of the utricle. From the lower part of the saccule a short canal, the **ductus reuniens** of Hensen, opens into the ductus cochlearis, a short distance in front of its vestibular or blind extremity. A second small channel, the **ductus endolymphaticus**, is continued from the posterior part of the saccule, and, passing between the utricle and the inner wall of the vestibule, is joined by a small canal, the **ductus utriculosaccularis**, which arises from the inner aspect of the utricle. It then enters and traverses the aqueductus vestibuli and ends, under the dura mater on the posterior surface of the petrous bone, in a dilated blind extremity, termed the recessus Cotugnii, or **saccus endolymphaticus**; this, according to Rüdinger, is perforated by minute foramina, through which the endolymph may pass into the meningeal lymphatics.

The vestibule also contains the blind extremity (cæcum vestibulare) of the ductus cochlearis, which lies immediately below the saccule in the recessus cochlearis of Reichert; from here it passes forwards into the spiral tube of the cochlea.

The walls of the utricle and saccule are composed of connective tissue which blends, along their attached surfaces, with the periosteal lining of the vestibule. It is modified internally to form a homogeneous membrana propria, which is covered by a layer of pavement epithelium and is thickened at the maculæ acusticæ. Towards the periphery of the maculæ the epithelium is cubical, while on them it is columnar.

The **structure of the maculæ** in the utricle and saccule is practically the same; two kinds of cells are found, viz. (*a*) supporting cells, and (*b*) hair cells. The **supporting cells** are somewhat fusiform, each containing, near its middle, a nucleus. Their branched, deep extremities are attached to the membrana propria; their free ends lie between the hair cells and form a thin inner limiting cuticle. The **hair cells** are flask-shaped and do not reach the membrana propria, but end in rounded extremities which lie between the supporting cells. Each contains, at its deepest part, a large nucleus, the rest of the cell being granular and pigmented. From the free end of each there projects a stiff, hair-like process, which, on the application of reagents, splits into several finer filaments. The nerve-fibres pierce the membrana propria, and end in arborisations around the deep extremities of the hair cells. A collection of small, rhombic crystals of carbonate of lime, termed **otoconia**, adheres to each of the maculæ.

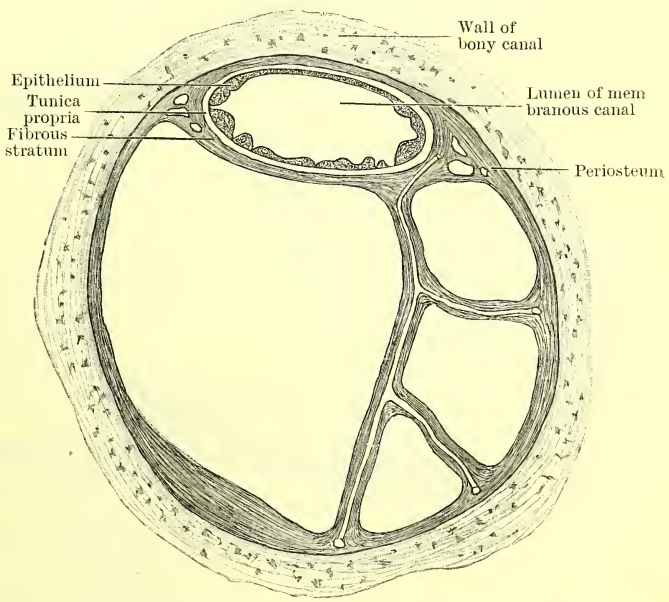


Fig. 593.—Transverse Section of Human Semicircular Canal (Rüdinger).

The **membranous semicircular canals** (ductus semicirculares) are elliptical on transverse section (Fig. 593), and are attached to the greater circumference of the bony tubes. The peripheral portion of the ellipse is fixed to the periosteal lining of the bony canal, whilst the opposite part is free, except that it is connected by irregular bands, the **ligamenta labyrinthi canaliculorum**, which pass through the perilymphatic space to the bony wall. Like the bony canals, each of the membranous canals is dilated at one extremity into an ampulla (ampulla membranacea), which is especially developed towards the concave aspect of the tube. While the membranous ampullæ nearly fill the corresponding portions of the bony tubes, the calibre of the remaining parts of the membranous canals is only equal to about one-fourth of that of the osseous canals.

Each membranous canal consists of three layers, viz.: (*a*) an outer **fibrous stratum** which contains blood-vessels, together with some pigment, and fixes the tube to the bony wall; (*b*) an intermediate, transparent **tunica propria**, presenting a number of papilliform elevations which project towards the lumen. The fibrous layer and tunica propria are thinnest along the attached surface of the tube, and in this region also the papilliform elevations are absent; (*c*) an internal **epithelial layer**, composed of pavement cells. In the ampullæ the tunica propria is much thickened, and projects into the cavity as a transverse elevation, termed the **septum transversum**, which, when seen from above, is somewhat fiddle-shaped; its most prominent part is covered by auditory epithelium forming the **crista acustica**, at each end of which is a half-moon-shaped border of small columnar cells, the **planum semilunatum**. The cells covering the crista acustica consist of **supporting cells** and **hair cells**, and are similar in their arrangement to those in the maculæ of the utricle and saccule. The hairs of the hair cells are, however, considerably longer, and project as far as the middle of the ampullary lumen. In fresh specimens they appear to end free, but in hardened preparations are seen to terminate in a soft, clear, dome-like structure, the **cupola terminalis**, which is striated, the striæ converging towards its concavity. The nerves form arborisations around the bases of the hair cells.

The **membranous cochlea** (ductus cochlearis or scala media) commences in the

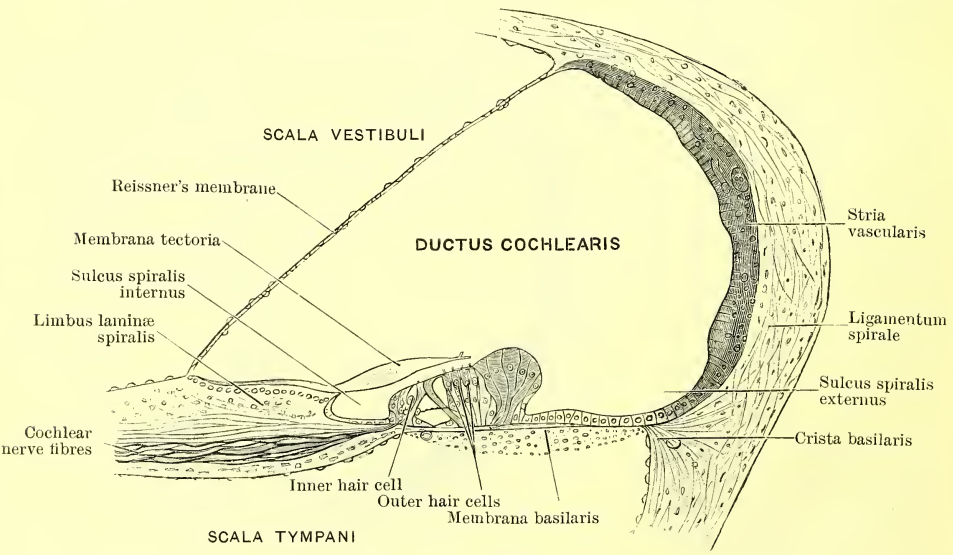


FIG. 594.—SECTION ACROSS THE DUCTUS COCHLEARIS (Retzius).

recessus cochlearis of the vestibule by a blind extremity (cæcum vestibulare), close to which it receives the ductus reuniens of Hensen (*vide* p. 763). It forms a spirally arranged canal inside the bony cochlea, and ends at the apex of the latter in a second blind extremity, the **lagena**, or cæcum cupulare, which is fixed to the cupola and partly bounds the helicotrema. As already stated (*vide* p. 761), the membrana basilaris extends from the free edge of the lamina spiralis ossea to the outer

wall of the cochlea. A second, more delicate membrane, the **membrane of Reissner**, or membrana vestibularis, stretches from the thickened periosteum covering the upper surface of the lamina spiralis ossea to the outer cochlear wall, some little distance above the external attachment of the membrana basilaris. A canal is thus enclosed between the underlying scala tympani and the overlying scala vestibuli, and constitutes the membranous cochlea or **ductus cochlearis**. Triangular on transverse section, it possesses a roof, an outer wall, and a floor, and is lined throughout with epithelium and filled with endolymph. On its floor the epithelium is greatly modified, and here are found the endings of the cochlear division of the auditory nerve.

The **roof** or **vestibular wall** of the ductus cochlearis is formed by the membrane of Reissner, which consists of a delicate, nearly homogeneous membrane, covered on its two surfaces by a layer of epithelium. Its entire thickness is about 3 μ.

The **outer wall** of the ductus cochlearis (Fig. 595) consists of the periosteal lining of the bony cochlea, which, however, is much thickened and greatly modified to form what is termed the **ligamentum spirale cochleæ**. Occupying the whole outer wall, this ligament projects inwards inferiorly as a triangular prominence, the **crista basilaris**, to which the outer edge of the membrana basilaris is attached. The fibres of the membrane radiate into the ligament in the form of a series of bundles analogous to the ligamentum pectinatum iridis. In the upper part of the ligamentum spirale the periosteum is of a reddish yellow colour, and contains, immediately under its epithelial lining, numerous small blood-vessels and capillary loops, forming the **stria vascularis**. The lower limit of this stria is bounded by a prominence, the **prominentia spiralis**, in which is seen a vessel, the **vas prominens**, and between this prominence and the crista basilaris is a concavity, the **sulcus spiralis externus**. The height of the outer wall diminishes towards the apex of the cochlea.

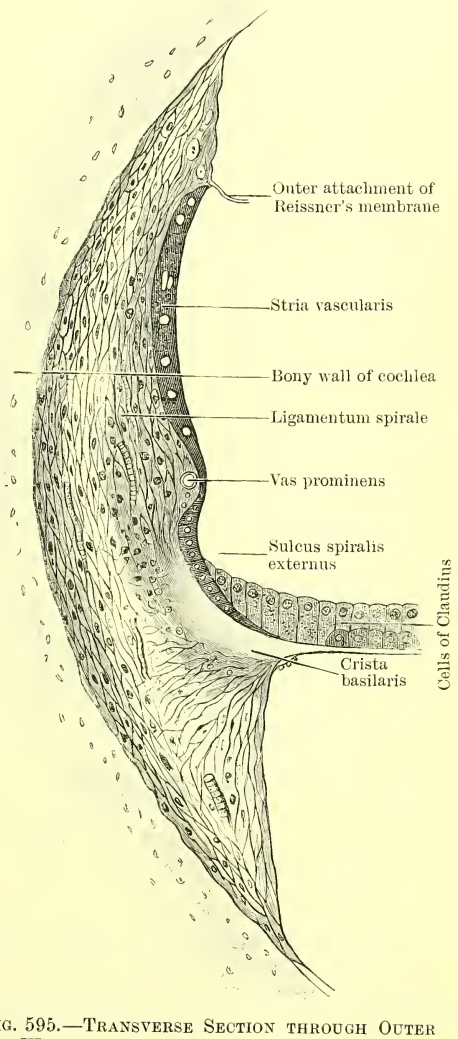


Fig. 595.—Transverse Section through Outer Wall of Ductus Cochlearis (Schwalbe).

The **floor** or **tympanal wall** of the ductus cochlearis is formed by the periosteum covering that portion of the lamina spiralis ossea which is situated to the outer side of Reissner's membrane, and by the **membrana basilaris**, which stretches from the free edge of the lamina spiralis ossea to the crista basilaris. On the inner part of the membrana basilaris the complicated structure termed the **organ of Corti** is situated. The lamina spiralis ossea consists of two plates of bone, between which are placed the canals for the branches of the cochlear nerve. On the upper plate the periosteum is thickened and modified to form the **limbus laminæ spiralis**, the outer extremity of which forms a C-shaped concavity, the **sulcus spiralis internus**. The portions of the limbus which project outwards, above and below this concavity, are termed respectively the **labium vestibulare** and **labium tympanicum**. The latter is perforated by some 4000 small apertures, the **foramina nervosa**, or habenula perforata, for the transmission of the cochlear nerves. Externally it becomes continuous with the

membrana basilaris. The upper surface of the labium vestibulare presents a number of furrows crossing each other nearly at right angles, and intersecting a series of elevations which, at the free margin of the labium, form a row of tooth-like structures, some 7000 in number, the **auditory teeth of Huschke**. Covering the limbus is a layer of apparently squamous epithelium; the deeper protoplasmic portions of the cells, however, with their contained nuclei, fill up the intervals between the elevations and auditory teeth. This layer of epithelium is continuous with that covering the under surface of Reissner's membrane and with that which lines the sulcus spiralis internus.

Membrana Basilaris.—The inner part of this membrane is thin, and supports the organ of Corti; it is named the **zona arcuata**, and reaches as far as the foot-plate of the outer rod of Corti. Its outer part, extending from the foot-plate of the outer rod of Corti to the crista basilaris, is thicker and distinctly striated, and is termed the **zona pectinata**. The substantia propria of the membrane is almost homogeneous, but exhibits, in its deeper part, numerous fibres. These fibres are most distinct in the zona pectinata, and number, according to Retzius, about 24,000. Covering the under surface of the membrana basilaris is a layer of connective tissue, which contains, in its inner part, small blood-vessels, one of which, larger than the rest, lies below the tunnel of Corti and is named the vas spirale. The width of the membrana basilaris increases from 210 μ in the basil coil to 360 μ in the apical coil.

Organ of Corti (Fig. 596).—Placed upon the inner portion of the membrana basilaris, the organ of Corti consists of an epithelial eminence which extends along the entire length of the ductus cochlearis, and comprises the following structures, viz.: (1) Corti's rods or pillars, (2) hair cells (inner and outer), (3) supporting cells of Deiters, (4) the cells of Hensen and Claudius, (5) the lamina reticularis, and (6) a cuticular membrane, the membrana tectoria.

The **rods of Corti** form two rows, **inner** and **outer**, of stiff, pillar-like structures, and each rod presents a base or foot-plate, an intermediate elongated portion, and an upper end or head. The bases of the two rows are planted on the membrana basilaris some little distance apart. The intermediate portions incline towards each other and the heads

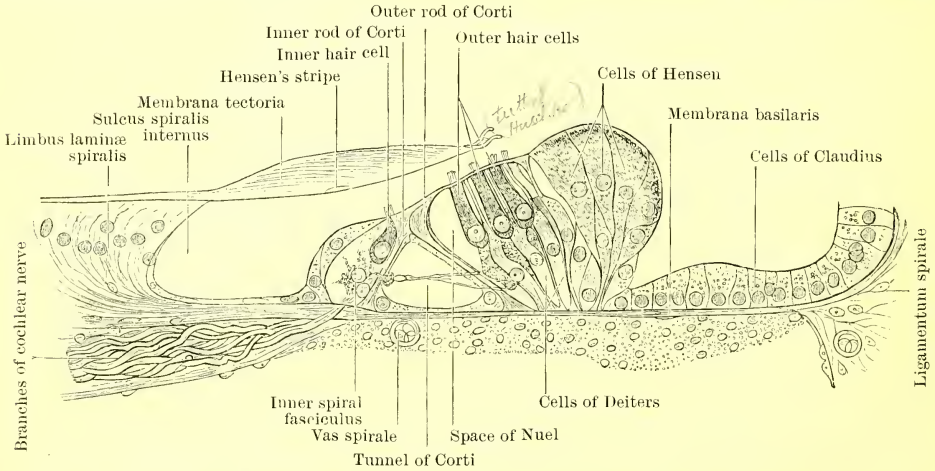


FIG. 596.—TRANSVERSE SECTION OF CORTI'S ORGAN FROM THE CENTRAL COIL OF COCHLEA (Retzius).

come into contact, so that, between the two rows above and the membrana basilaris below, there is enclosed a triangular tunnel, the **tunnel of Corti**; this tunnel increases both in height and width on passing towards the apex of the cochlea. The **inner rods** number nearly 6000, and the head of each resembles somewhat the upper end of the ulna, presenting a deep concavity, externally, for the reception of a corresponding convexity on the head of the outer rod. The part of the head which overhangs this concavity is prolonged outwards, under the name of the **head-plate**, and overlaps the head of the outer rod. The expanded bases of the inner rods are situated on the innermost portion of the membrana basilaris, immediately to the outer side of the foramina nervosa of the labium tympanicum. The intermediate parts of the inner rods are sinuously curved, and form, with the

membrana basilaris, an angle of about 60°. The **outer rods** number about 4000, and are longer than the inner, especially in the upper part of the cochlea. They are more inclined towards the membrana basilaris, and form with it an angle of about 40°. The head of each is convex internally, to fit the concavity on the head of the inner rod, and is prolonged outwards as a plate, the **phalangeal process**, which becomes connected with the lamina reticularis. In the head is an oval body which has an affinity for certain reagents. The main part of each rod consists of a nearly homogeneous material, which is finely striated. At the bases of the rods, on the side next the tunnel, is a nucleated mass of protoplasm which reaches as far as the heads of the rods, and covers also the greater part of the tunnel floor. This may be regarded as the undifferentiated part of the cell from which the rod was developed. Slit-like intervals, for the transmission of nerves, exist between the intermediate portions of adjacent rods.

Hair Cells.—These, like Corti's rods, form two sets, **inner** and **outer**. The former consists of a single row lying immediately internal to the inner rods—the latter of three, or, it may be, four rows placed to the outer side of the external rods. The **inner hair cells** are about 3500 in number, and have a greater diameter than the inner rods, and so each is supported by more than one rod. Somewhat oval in shape, their free extremities are surmounted by about twenty fine hair-like processes, arranged in the form of a crescent, with its concavity directed inwards. The deep end of the cell is rounded, and contains a large nucleus. It reaches only about half-way down the rod, and in contact with it are the arborisations of the nerve terminations. To the inner side of this row of hair cells are two or three rows of elongated columnar cells, which act as supporting cells, and are continuous with the low columnar cells lining the sulcus spiralis internus. The **outer hair cells** number about 12,000, and form three rows in the basal coil and four rows in the upper two coils, although in the higher coils the rows are not so regularly arranged. Their rounded free extremities support some twenty hairlets arranged in the form of a crescent, opening inwards. Their deep extremities reach about half-way to the membrana basilaris, and are in contact with the nerve arborisations.

Alternating with the rows of the outer hair cells are the rows of **Deiters' supporting cells**, the lower extremities of which are expanded on the membrana basilaris, whilst their upper ends are tapered ; the nucleus is placed near the middle of each cell, and, in addition, each cell contains a bright, thread-like structure called the **supporting fibre**. This fibre is attached by a club-shaped base to the membrana basilaris, and expands, at the free end of the cell, to form a **phalangeal process** of the membrana reticularis.

The **cells of Hensen**, or outer supporting cells, consist of about half a dozen rows, immediately outside Deiters' cells, and form a well-marked elevation on the floor of the ductus cochlearis. Their deep extremities are narrow and attached to the membrana basilaris, while their free ends are expanded ; each cell contains a distinct nucleus and some pigment granules. The columnar cells, situated externally to the cells of Hensen, cover the outer part of the zona pectinata, and are named the **cells of Claudius.** A space, the **space of Nuel**, exists between the outer rods of Corti and the neighbouring row of hair cells. It communicates internally with Corti's tunnel, and extends outwards between the outer hair cells as far as Hensen's cells.

The **lamina reticularis** is a thin cuticular structure which lies over Corti's organ, and extends from the heads of the outer rods as far as Hensen's cells, where it ends in a row of quadrilateral areas which form its outer border. On looking at it from above it is seen to consist of two or three rows of structures, named **phalanges**, which are elongated cuticular plates resembling in shape the digital phalanges. The innermost row is formed by the phalangeal processes of the heads of the outer row of Corti's rods ; the succeeding row, or rows, represent the expanded upper ends of Deiters' supporting cells. The number of rows of phalanges, therefore, varies with the number of rows of outer hair cells and the alternating cells of Deiters. The phalanges separate the free ends of the hair cells from each other, since these are seen to occupy the somewhat circular apertures between their constricted middle portions.

The **membrana tectoria** (Fig. 596) is an elastic membrane overlying the sulcus spiralis internus and the organ of Corti. Attached, by its inner end, to the limbus laminæ spiralis, near the lower edge of Reissner's membrane, it reaches outwards as far as the outer row of hair cells. Its inner portion is thin and overlies the auditory teeth of Huschke. Its outer part is, at first, much thickened, but becomes attenuated near its external border, which, according to Retzius, is attached to the outer row of Deiters' cells. Its lower edge presents a firm, homogeneous border, and opposite the inner row of hair cells contains a clear, spirally arranged band, named **Hensen's stripe.** Probably the membrana tectoria acts as a damper comparable to the otoconia in the utricle and saccule.

Auditory Nerve (Fig. 597).—The auditory nerve consists of two main parts, the **ramus vestibularis** and the **ramus cochlearis**; as the former traverses the internal auditory meatus it presents a gangliform swelling, the **ganglion of Scarpa**. The

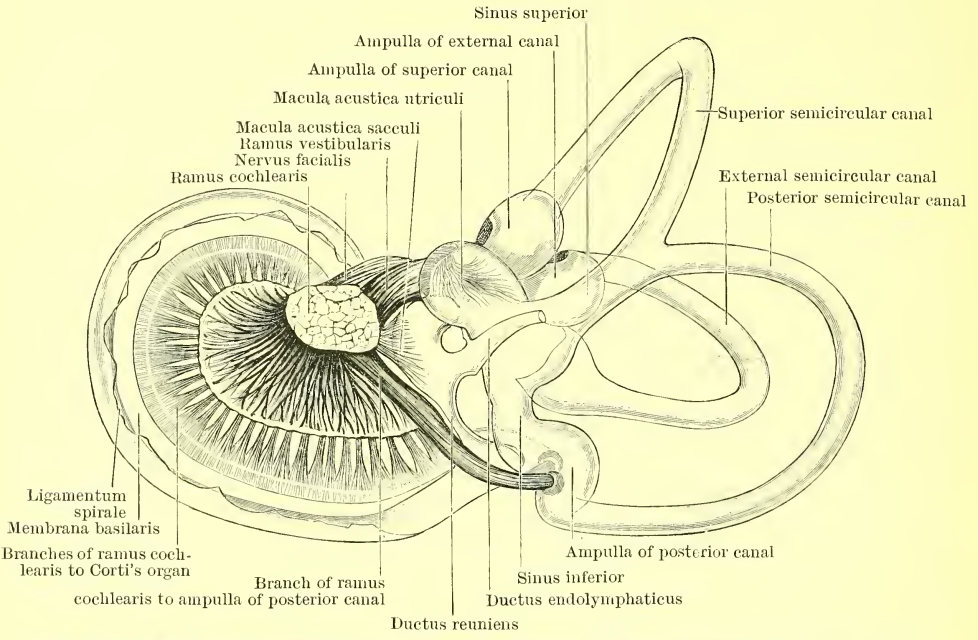


FIG. 597.—MEMBRANOUS LABYRINTH OF A FIVE MONTHS' FŒTUS, viewed from its postero-mesial aspect (Retzius).

ramus vestibularis divides into three branches, the filaments of which pass through the foramina in the area vestibularis superior, and are distributed to the macula acustica utriculi and the ampullæ of the superior and external semicircular canals. The ramus cochlearis gives off a branch to the macula acustica sacculi and another to the ampulla of the posterior semicircular canal. The former exhibits a gangliform swelling beyond which its filaments pass through the foramina in the area vestibularis inferior; the latter is transmitted through the foramen singulare, and in this part of its course the nerve possesses two gangliform enlargements. The remainder of the ramus cochlearis is distributed to the hair cells of Corti's organ, the branches for the basal and middle coils entering the foramina in the tractus spiralis foraminosus, those for the apical coil passing up through the canalis centralis of the modiolus. Extending upwards, in the bony canals of the modiolus, the nerve-fibres radiate outwards between the lamellæ of the lamina spiralis ossea. Contained in the spiral canal of the modiolus, near the attached margin of the lamina, is a ganglion which winds spirally round the modiolus, and is named the **ganglion spirale** or ganglion of Corti (Fig. 598). It consists of bipolar nerve-cells, and each nerve fibre, probably, has its continuity interrupted by one of these cells. Beyond the ganglion spirale the nerve-fibres extend outwards, at first in bundles, and then in a more or less continuous sheet, from the outer edge of which they are again collected into bundles, which pass through the foramina nervosa of the labium tympanicum. Beyond this they appear as naked axis-cylinders, and, turning in a spiral manner (**inner** or **first spiral fasciculus**), send fibrillæ towards the

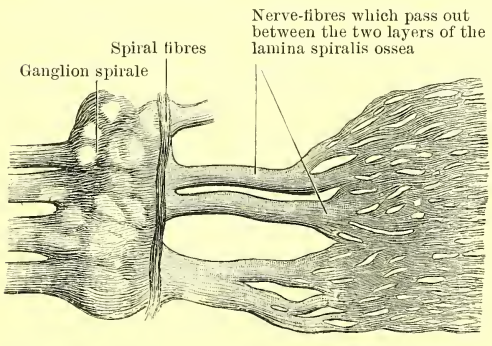


FIG. 598.—PART OF COCHLEAR NERVE, highly magnified (Henle).

inner row of hair cells. Other fibrils pass outwards between the inner rods and form a **second spiral fasciculus** in Corti's tunnel, from which fibrils extend outwards across the tunnel, and, passing between the outer rods, enter Nuel's space. They form a spiral fasciculus on the inner aspect of each row of Deiters' cells, and from these fasciculi fibrillæ pass towards the bases of the outer hair cells.

Schwalbe divides the auditory nerve into three portions, viz. : (1) **ramus utriculo-ampullaris**, corresponding with the ramus vestibularis already described ; (2) **ramus sacculo-ampullaris**, for the saccule and posterior ampulla ; and (3) **ramus cochlearis**, for the ductus cochlearis.

Vessels of the Internal Ear.—The **auditory artery**, a branch of the basilar, enters the internal auditory meatus and divides into vestibular and cochlear branches. The vestibular branch supplies the soft tissues in the vestibule and semicircular canals, each canal receiving two arteries, which, starting from opposite extremities of the canal, anastomose on the summit of the arch. The cochlear branch divides into numerous twigs, which enter the foramina in the tractus spiralis foraminosus, and run outwards in the lamina spiralis ossea to reach the soft structures ; the largest of these arteries runs in the canalis centralis. The stylo-mastoid artery also supplies some minute branches to the cochlea. Siebenmann describes the auditory artery as dividing into three branches, viz. : (1) anterior vestibular, (2) cochlear proper, and (3) vestibulo-cochlear. The **veins** from the cochlea and vestibule unite at the bottom of the meatus with the veins from the semicircular canals to form the **internal auditory vein**, which may either open into the posterior part of the inferior petrosal sinus or into the lateral sinus. Small veins also pass through the aqueductus cochleæ and aqueductus vestibuli, the former opening into the inferior petrosal sinus or into the internal jugular vein, the latter into the superior petrosal sinus.

Development of Labyrinth.

The epithelial lining of the labyrinth is derived from an invagination of the cephalic ectoderm, termed the **auditory pit**, which appears opposite the hind brain immediately above the first visceral cleft. The mouth of the pit is closed by the growing together of its margins, and it then assumes the form of a hollow vesicle, the **otic vesicle**, lined by epithelium ; the vesicle sinks into the subjacent mesoderm, and is met by the auditory nerve growing out from the neural crest. The vesicle soon becomes pear-shaped ; its upper tapering part is named the **recessus labyrinthi**, and forms the future ductus endolymphaticus. About the fifth week, the lower part of the vesicle is prolonged forwards as a tubular elongation, the future ductus cochlearis. This is at first straight, but soon becomes curved on itself, so that at the twelfth week all three coils are differentiated. From the upper part of the vesicle the semicircular canals are developed, and appear as hollow, disc-like evaginations, the central parts of the two walls of which coalesce and disappear, leaving only the peripheral rings or canals. The three canals are free about the beginning of the second month, and are developed in the following order, viz. : superior, posterior, and external. The intermediate part of the otic vesicle represents the vestibule, and is divided by a constriction into an anterior part, the saccule, communicating with the ductus cochlearis, and a posterior portion, the utricle, receiving the extremities of the semicircular canals. The constriction extends for some distance into

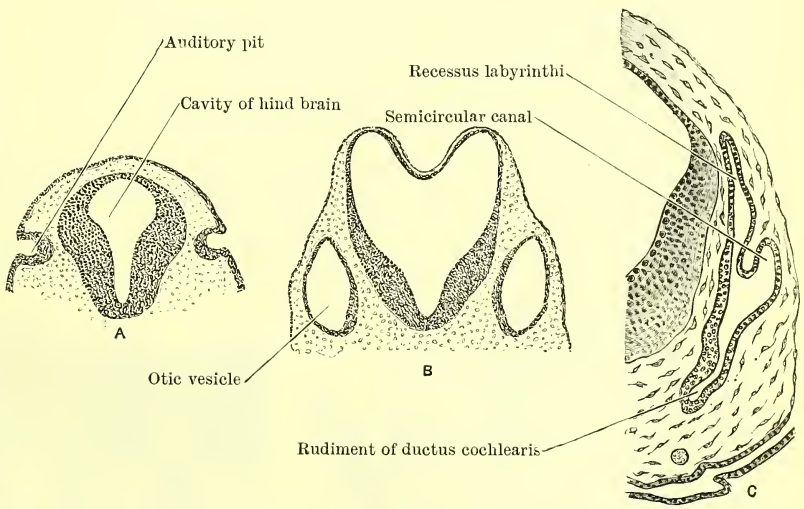


Fig. 599.—Sections through the Region of the Hind Brain of Fœtal Rabbits (to illustrate the development of the labyrinthine epithelium).

In A the ectoderm is invaginated to form the auditory pit ; in B the auditory pit is closed and detached from the ectoderm, forming the otic vesicle ; while C shows a further stage in the development of the vesicle.

the ductus endolymphaticus, and thus the utricle and saccule are only indirectly connected by a Y-shaped tube. Another constriction makes its appearance between the saccule and the ductus cochlearis near its commencement, and forms the **canalis reuniens** of Hensen. The epithelial lining is at first columnar, but becomes cubical throughout the whole labyrinth, except opposite the terminations of the auditory nerve, where it forms the columnar epithelium of the maculæ of the utricle and saccule, of the cristæ ampullæ, and of the organ of Corti. On the floor of the ductus cochlearis two ridges appear, of which the inner forms the limbus laminæ spiralis, whilst the cells of the outer become modified to form the rods of Corti, the hair cells, and the supporting cells of Deiters and Hensen.

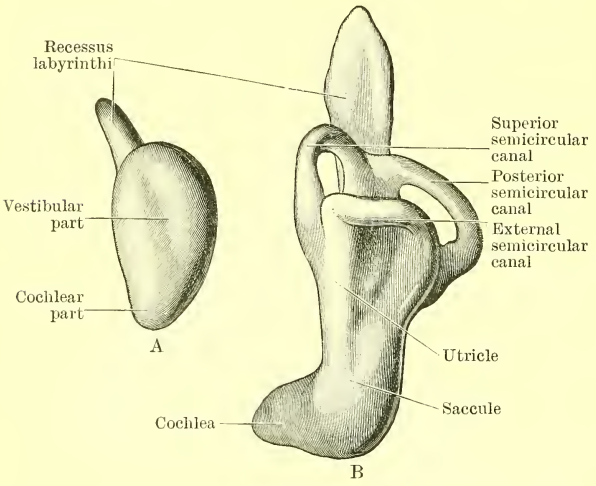


FIG. 600.

A, Left labyrinth of a human embryo of about four weeks; B, Left labyrinth of a human embryo of about five weeks (from W. His, jun.)

The mesoderm surrounding the otic vesicle is differentiated into: (1) a fibrous layer, the wall of the membranous labyrinth; (2) a cartilaginous external capsule, the future petrous bone; and (3) an intervening layer of gelatinous tissue, which is ultimately absorbed to form the perilymphatic space between the bony and membranous labyrinths.

ORGANS OF TASTE.

The peripheral organs of the sense of taste (organon gustus) consist of groups of modified epithelial cells, termed the **taste buds**, which are found on certain parts of the tongue and its immediate neighbourhood.

Taste buds are present in large numbers around the circumference of the papillæ vallatæ, while some are also found on their opposing walls (Fig. 601). They

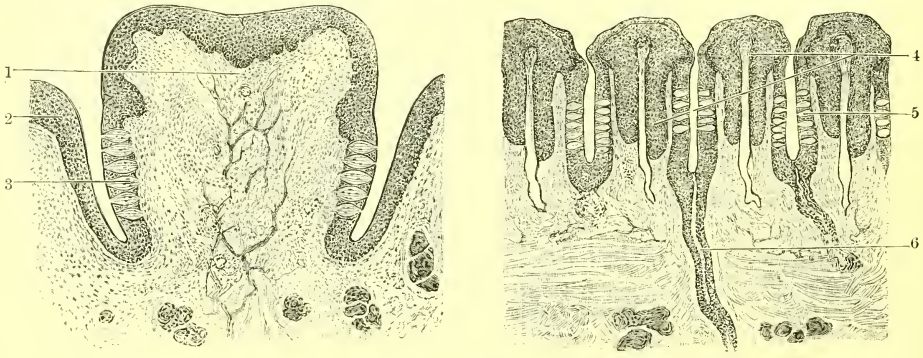


FIG. 601.

A, Section through a papilla vallata of human tongue. B, Section through a part of the papilla foliata of a rabbit.

1. Papilla. 2. Vallum 3. Taste buds. 4. Papillæ. 5. Taste buds. 6. Duct of serous gland.

are very numerous over the fimbriæ linguæ, which correspond with the papillæ foliatæ of the tongue of the rabbit, and are also found over the posterior part and sides of the tongue, either on the papillæ fungiformes or throughout the stratified epithelium. They exist, also, on the buccal surface of the soft palate and on the posterior aspect of the epiglottis.

Structure of Taste Buds (Fig. 602).—They are oval or flask-shaped, and occupy nests in the stratified epithelium of the regions mentioned. The deep extremity of each is somewhat expanded and rests upon the corium; the free end is perforated by a minute pore, termed the **gustatory pore**. They consist of modified epithelial cells, which are grouped under the two varieties of—(*a*) supporting cells,

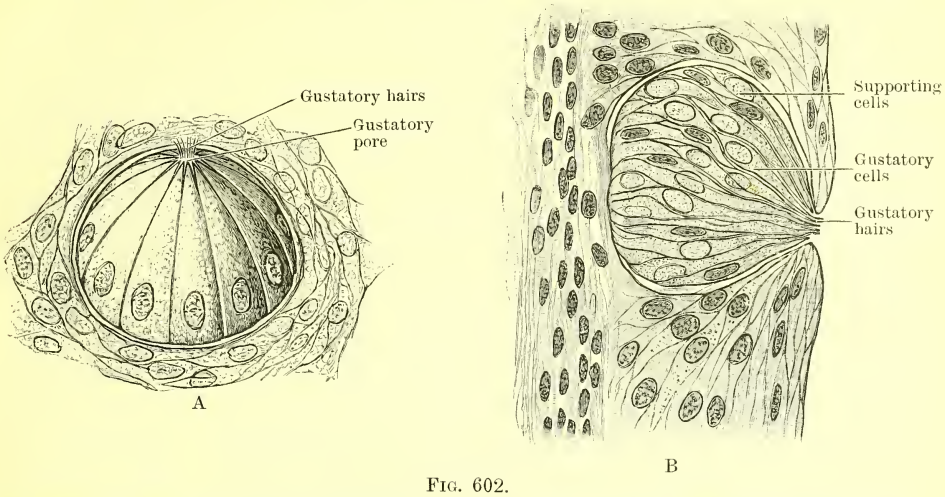


FIG. 602.

A, Three-quarter surface view of taste bud from the papilla foliata of a rabbit (highly magnified).

B, Vertical section of taste bud from the papilla foliata of a rabbit (highly magnified).

and (*b*) gustatory cells (Fig. 603). The **supporting cells** are elongated, nucleated spindles, and are mostly arranged like cask staves to form the outer envelope of the bud. Some are, however, found in the interior of the bud, amongst the **gustatory cells**. The latter occupy the centre of the bud, and present a nucleated cell-body, which is prolonged into a peripheral and a central process. The peripheral process is rod-like and almost hyaline, and terminates at the gustatory pore in a hair-like filament, **gustatory hair**. The central process passes inwards towards the deep extremity of the bud, where it ends free, either in a single varicose filament or by becoming bifurcated or branched.

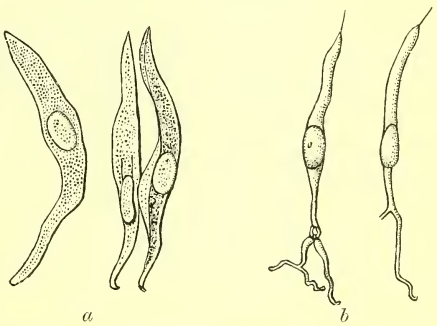


FIG. 603.—ISOLATED CELLS FROM TASTE BUD OF RABBIT (Engelmann).

a, Supporting cells. *b*, Gustatory cells.

Nerves of Taste.—The nerve which supplies the taste buds over the anterior part of the tongue is probably the chorda tympani, which, although a branch of the facial nerve, is generally regarded as being continuous with the pars intermedia of Wrisberg; that for the posterior part is the glosso-pharyngeal. The internal laryngeal branch of the vagus nerve supplies the epiglottis, together with a small area of the tongue immediately in front of it. The nerve fibrils, having lost their medullary sheaths, ramify partly between the gustatory cells and partly amongst the cells of the bud capsule. It was formerly thought that the nerve-fibrils were directly continuous with the central ends of the gustatory cells, but this view is no longer entertained.

The ducts of Ebner's glands open into the bottom of the valleys surrounding the papillæ vallatæ, and the serous-like secretion of these glands probably washes the free hair-like extremities of the gustatory cells, and so renders them ready to be stimulated by successive substances. It should be added that there is a close association between the senses of smell and taste. This can be best appreciated by considering the defective taste perceptions resulting from inflammatory conditions of the nasal mucous membrane, or the common practice of holding the nose in order to minimise the taste of nauseous drugs.

THE SKIN OR INTEGUMENT.

ORGANS OF TOUCH.

The Skin.

The **skin** (integumentum commune) covers the body, and is continuous, at the orifices on its surface, with the mucous lining of its alimentary and other canals. It contains the peripheral terminations of the sensory nerves, and serves as an organ of protection to the deeper tissues. It is the chief factor in the regulation of the body temperature, and by means of the sweat and sebaceous glands, which open on its free surface, constitutes an important excretory structure. Its superficial layers are modified to form appendages in the shape of hairs and nails.

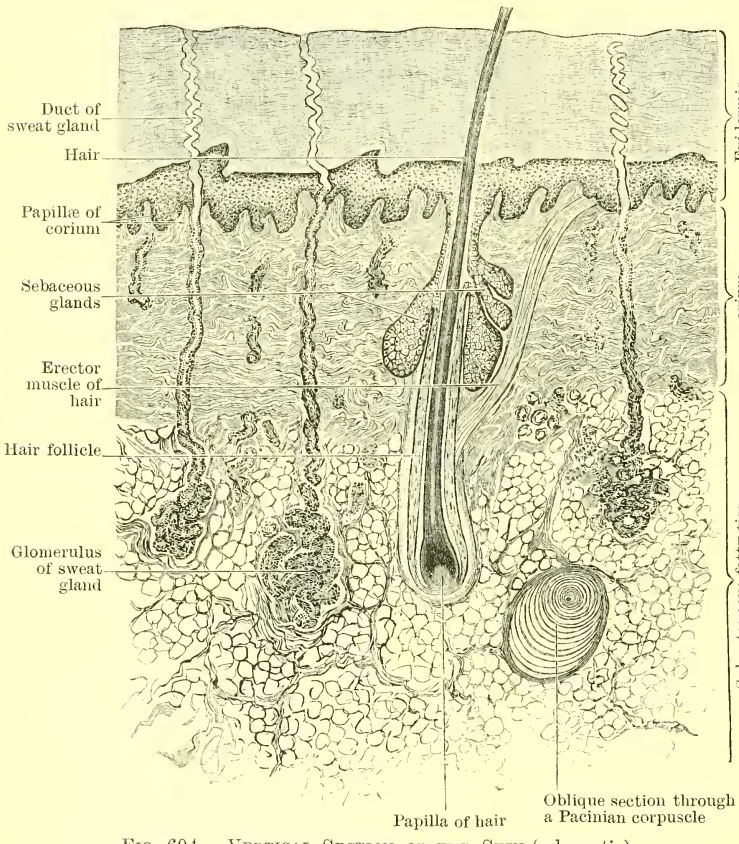


Fig. 604.—Vertical Section of the Skin (schematic).

The superficial area of the skin averages about one and a half square metres, whilst its thickness varies from 0·5 to 4 mm., being greatest on the palms of the hands and soles of the feet, and on the back of the neck and shoulders, and least on the eyelids and penis. It is very elastic and resistant, and its colour, determined partly by its own pigment and partly by that of the blood, is deeper on exposed parts and in the regions of the genitals, axillæ, and mammary areolæ, than elsewhere. The colour also varies with race and age, the different races of the world being roughly classified, according to the colour of their skin, into the three groups of white, yellow, and black. Pinkish in colour in childhood, the skin assumes a yellowish tinge in old age, while in certain diseases (*e.g.* icterus and melasma Addisonii) it undergoes marked alteration.

The surface of the skin is perforated by the hair follicles and by the ducts of the sweat and sebaceous glands, and on the palms, soles, and flexor aspect of the digits it presents numerous permanent ridges (cristæ cutis) which correspond with rows of underlying papillæ. Over the terminal phalanges these ridges form distinctive patterns, which are retained from youth to old age, and are utilised for purposes of identification. Folds of the skin (retinacula cutis) are seen in the neighbourhood of the joints, and it can be thrown into wrinkles by the contraction of the subcutaneous muscles, where these exist. Over the greater part of the body it is freely

movable; but on the scalp and outer surface of the pinna, as well as on the palms and soles, it is bound down to the subjacent tissues.

The skin consists of two strata, viz.: a deep, termed the dermis or corium, and a superficial, named the epidermis (Fig. 604).

The **corium** gives elasticity and sensibility to the skin, and consists essentially of a felted interlacement of connective tissue and elastic fibres. In its deeper part, or **stratum reticulare**, the fibrous bundles are coarse and form an open network, in the meshes of which are vessels, nerves, pellets of fat, hair follicles, and glands. This reticular stratum passes, as a rule, without any line of demarcation, into the panniculus adiposus or subcutaneous fatty tissue, but in some parts it rests upon a layer of striped or unstriped muscular fibres—the latter in the case of the scrotum. In the superficial layer, or **stratum papillare**, of the corium, the connective tissue-bundles are finer and form a close network. Projecting from its free surface are numerous finger-like, single, or branched elevations, termed **papillæ** (Fig. 605), the free ends of which are received into corresponding depressions on the under surface of the epidermis. These papillæ vary in size, being small on the eyelids, but large on the palms and soles, where they may attain a length of 225 μ, and produce the permanent curved ridges already alluded to. Each ridge usually contains two rows of papillæ, between which the ducts of the sweat glands pass to reach the surface. The papillæ consist of fine connective tissue and elastic fibres, mostly arranged parallel to the long axis of the papilla. The majority contain capillary loops, but some the terminations of nerves. The superficial surface of the corium is covered by a thin, homogeneous basement membrane.

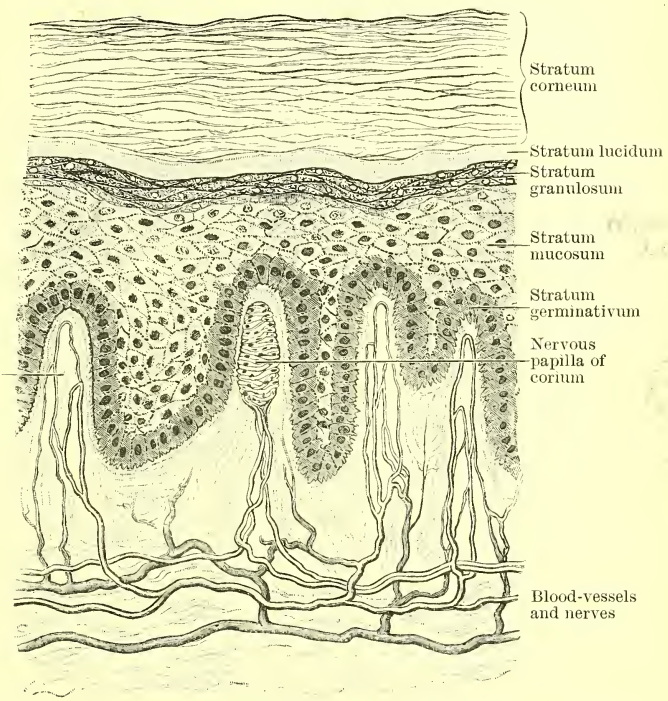


Fig. 605.—Vertical Section of Epidermis and Papillæ of Corium (highly magnified).

The **epidermis** covers the corium; it is non-vascular and consists of stratified epithelium. Its superficial layers are modified to form the **stratum corneum**, or **horny layer** of the skin, which may be separated by maceration or blistering from the deeper, softer portion, or **stratum mucosum** (Malpighi). The epidermis consists from within outwards of the following five strata (Fig. 605):—

1. The **basilar layer**, or **stratum germinativum**, which comprises a single stratum of nucleated columnar cells planted by denticulated extremities on the basement membrane of the corium.

2. The **stratum mucosum**, which consists of six or eight layers of polygonal, nucleated "prickle" or "finger" cells, the processes of which join those of adjacent cells. Between the cells of this layer are minute channels, in which leucocytes or pigment granules may be seen. The cells of the stratum mucosum are characterised by the presence of numerous epidermic fibrils, which are coloured violet by hæmatoxylin and red by carmine. These fibrils are unaffected by boiling, but swell up under the action of acids and alkalies, and form the filaments of union

between adjacent cells. On account of their presence, L. Ranvier (*Compt. rend.*, Paris, Jan. 1899, tome cxxviii.) has named this layer the **stratum filamentosum**. The dark colour of the negro's skin is caused by the presence of numerous pigment granules in the deeper layers of this stratum; the pigment—of which *melanin* forms an important constituent—is absent from the more superficial layers of the epidermis.

3. The **stratum granulosum**, which comprises two or three layers of horizontally arranged, flattened cells, scattered around the nuclei of which are elliptical or spherical granules of *eleidin*, a substance staining deeply with carmine, and probably representing an intermediate stage between the protoplasm of the deeper cells and the keratin of the superficial layers.

4. The **stratum lucidum**, which is an apparently homogeneous layer, but is in reality made up of several strata of flattened or irregular squames, some of which may contain eleidin granules.

5. The **stratum corneum**, which comprises several layers of flattened non-nucleated squames, the more superficial of which are from time to time removed by friction, and may be seen partly detached on the surface. Ranvier named these partly detached squames the **stratum disjunctum**. The deeper cells contain granules of a fatty material which has the consistency and plasticity of beeswax, and stains with osmic acid. The peripheral parts of the cells consist of **keratin**, a highly resistant substance which is unaffected by mineral acids, and is indigestible in pepsin-hydrochloric acid. Macleod (*Proceedings of the Anatomical Society of Great Britain and Ireland*, May, 1902) found that after digestion of the stratum corneum in the latter fluid the cells "presented the appearance of a fine network, like a honeycomb, the contents of which had completely gone. The periphery of the cell alone resisted the action of the pepsin and had become keratinised."

L. Ranvier (*op. cit.*) has pointed out that the **stratum lucidum** is really double, and has named the deeper of its two layers the **stratum intermedium**; this he describes as consisting of two or three layers of clear cells with atrophied nuclei, while in the cell-walls the epidermic fibrils "are rolled up like the threads of a cocoon."

Regeneration of the epidermis is generally regarded as taking place by cell proliferation in the stratum germinativum, the young cells gradually passing through the polyhedral and granular stages, and ultimately becoming the horny squames of the stratum corneum. Professor Thomson of Oxford considers that, although this view meets all the requirements in white races, a difficulty is met with if it is applied to coloured races, where most pigment is found in the deeper cells of the stratum mucosum, while the superficial layers are free from colour. If the deeper cells advance to the surface, it is only reasonable to suppose that they would carry their pigment with them. This theory, therefore, necessitates a satisfactory explanation of the disappearance of the pigment from the superficial layers. He suggests that possibly the growth of the epidermis is analogous to the growth of the cork cambium of plants, the stratum mucosum corresponding to the green cells, and the stratum corneum to the corky layer of the cambium. If such be the case—and he insists that there is much evidence in support of it—the deeper cells would advance inwards towards the corium, and the superficial cells would grow outwards towards the surface. Under this view the active layers would be the stratum granulosum and stratum lucidum, and by it many of the difficulties would be explained, including the mysterious disappearance of the pigment from the superficial layers; it would also afford a reasonable explanation of how it happens that, in old age, a negro's hair becomes white, while his skin retains its blackness.

Vessels and Nerves of the Skin.—The **arteries** form a plexus in the subcutaneous tissue from which branches extend into the corium, where they supply the hair follicles and glands, and form a second plexus under the papillæ, to which small loops are given. The **veins** and **lymphatics** commence in the papillæ, and, after forming a subpapillary plexus, open into their respective subcutaneous vessels.

The **nerves** of the skin vary in number in different parts of the body, being extremely numerous where the sense of touch is acute, *e.g.* on the palmar aspect of the terminal phalanges, while in the skin of the back, where the sensibility is less, they are fewer in number. They form a plexus in the corium, and either terminate amongst the cells of the epidermis, or in special end organs named **tactile corpuscles**. Those ending in the epidermis form a rich subepithelial plexus, from which delicate fibrils pass between the cells of the rete mucosum, where they become beaded, and end in rounded swellings on flattened discs—the **tactile discs** of Ranvier.

The **special end organs** are of three chief varieties (Fig. 606): (*a*) **Corpuscula bulboidea** (Krausii), found on the lips, glans penis, etc., and consisting of a connective tissue capsule enclosing a core of elongated and polygonal cells, amongst which the axis-cylinder of the nerve fibril becomes branched and its ramifications end in clubbed extremities. (*b*) **Corpuscula lamellosa** (Vateri and Pacini). These are small, oval bodies, with a long diameter of 2 to 3 mm., and are found in the subcutaneous tissue attached to the nerve trunks. They are very numerous on the digital nerves, but are present in many other situations, *e.g.* in the mesentery. Each possesses a sheath, consisting of a number of concentrically arranged connective tissue lamellæ, covered by endothelium continuous with the perineurium. The central part of each corpuscle consists of a soft, almost homogeneous core. The nerve-fibre passes along the centre of the stalk of the corpuscle, and, reaching the core, loses its medullary sheath, whilst its axis-cylinder passes into the core and becomes branched near its distal extremity, the branches ending in bulbous enlargements. (*c*) **Corpuscula tactus** (Meissneri). These are very numerous on the flexor aspect of the hands and feet, and especially so in the skin over the terminal phalanges; but they also exist in other parts of the body. They occupy certain of the papillæ of the corium, and are oval in shape, their long diameter in the hand being from 110 μ to 160 μ. They consist of a connective tissue capsule, which sends imperfect septa into the interior of the corpuscle. One or two nerve-fibres perforate the capsule, either directly or after taking a spiral course around it; and losing, as a general rule, their medullary sheath, their axis-cylinders break up into fibrils, which end in globular or discoid enlargements.

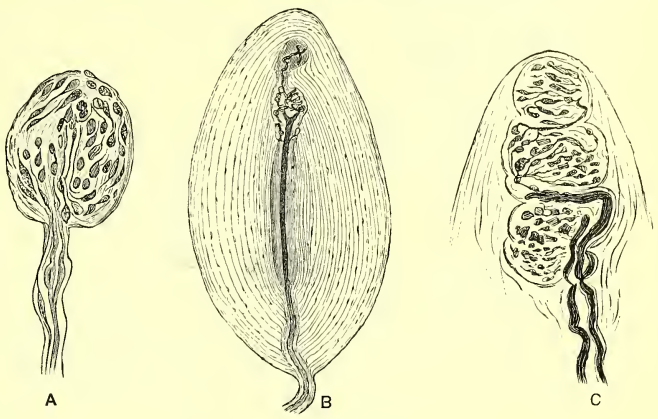


Fig. 606.—Tactile Corpuscles.

A, End bulb (Krause).
B, Corpuscle of Pacini } (after Ranvier).
C, Corpuscle of Meissner }

Ruffini has described a special variety of terminal corpuscle in the human finger. They are termed **Ruffini's endings**, and are situated either at the junction of the corium and subcutaneous tissue, or are embedded in the latter. Of an oval shape, they consist of a connective capsule within which the axis-cylinder divides into varicose filaments, and these terminate in small knobs.

Appendages of the Skin.

The appendages of the skin comprise the nails, the hairs, the sebaceous, and the sudoriparous or sweat glands.

Nails.—The nails or ungues (Figs. 607, 608) are epidermal structures, and, in man, represent the hoofs and claws of the lower animals. The **root** of the nail, or radix unguis, is hidden from view and embedded in a fold of skin; the **body** (corpus unguis), or uncovered part, rests on the corium and ends in a **free edge** (margo liber). The greater part of the lateral margins is overlapped by a duplicature of skin, termed the **nail-wall** or **vallum unguis**. The nails are pink in colour, with the exception of a small semilunar area near the root, which is more opaque than the rest, and is named the **lunula**. The lunulæ diminish in size from the thumb towards the little finger, while the thickness of the nail diminishes towards its root and lateral margins. The corium under the nail is highly vascular and sensitive, and presents, especially under the anterior part of the body, numerous longitudinally arranged papillæ. The part of the corium under the body is termed the **nail bed**; that under the root, the **nail matrix**. The deep part of the nail consists of

the stratum germinativum and stratum mucosum, while its superficial horny portion is constituted by a greatly thickened stratum lucidum, and consists of nucleated, keratinised squames. The stratum corneum is represented by the thin cuticular fold overlapping the lunula, and termed the **eponychium**, while the stratum granulosum can only be traced as far forwards as the nail root.

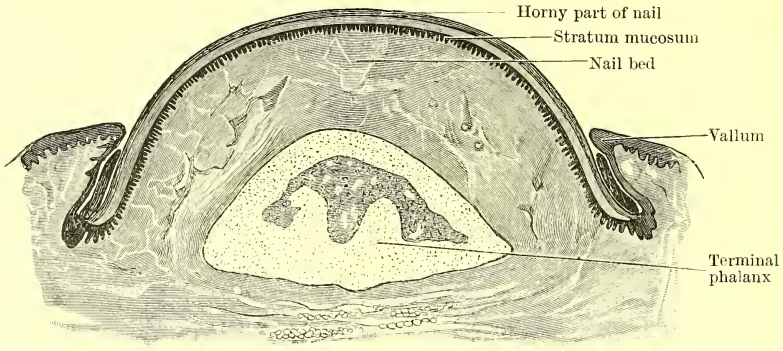


Fig. 607.—Transverse Section of a Nail.

Hairs.—Hairs (pili) are well developed on the scalp, pubes, and margins of the eyelids, in the axilla, the vestibule of the nose, and at the entrance to the concha, and also on the face of the male. Those on the genitals and face appear about puberty. Rudimentary over the greater part of the body, they are entirely absent on the flexor surfaces of the hands and feet, over the dorsal aspect of the terminal

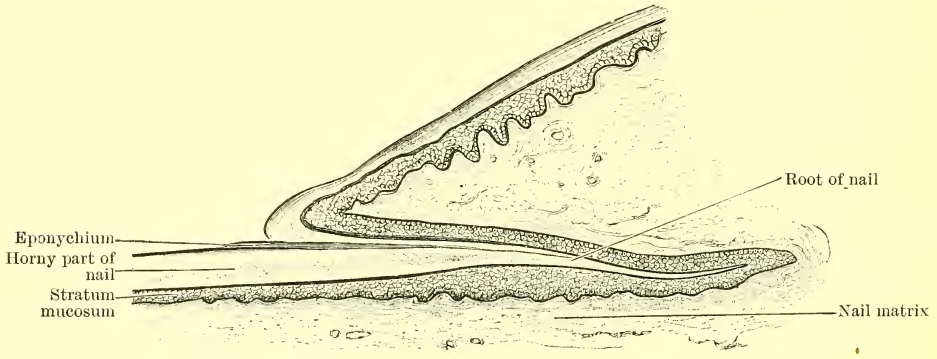


Fig. 608.—Longitudinal Section through Root of Nail.

phalanges, the glans penis, the inner surface of the prepuce, and inner aspect of the labia. Marked variations, individual and racial, exist as to the colour of the hair, and also as to the manner of its growth; hence the terms straight, curly, woolly, etc. are used to designate it. Straight hairs are coarser than curly ones, and have, moreover, a circular or oval outline on transverse section, curly hairs being flat and riband-like.

The **root of the hair** (radix pili) is embedded in a depression of the skin, termed the **hair follicle** (Fig. 604); while the free portion is named the **stem** or **shaft**, and consists from without inwards of three parts, viz. cuticle, cortex, and medulla. The *cuticle* is formed by a layer of imbricated scales which overlap one another from below upwards. The *cortex* consists of longitudinally arranged fibres made up of elongated, closely applied, fusiform cells, which contain pigment and sometimes air spaces, the latter especially in white hairs. The *medulla*, absent from the fine hairs of the body generally and from the hairs of young children, forms a central core, which appears black by transmitted, and white by reflected light, and is composed of polyhedral nucleated cells containing pigment, fat granules, and air spaces.

The **hair follicle** (folliculus pili) consists of an oblique or curved—the latter in

curly hairs—invagination of the epidermis and corium, which in the case of large hairs extends into the subcutaneous tissue (Fig. 604); some little distance below its orifice the ducts of the sebaceous glands open into it. The portion of the follicle derived from the corium (dermic coat) consists of a fibrous sheath of external longitudinal and internal circular connective tissue fibres, the latter being lined by a hyaline layer directly continuous with the basement membrane of the corium. The parts of the follicle derived from the epidermis are named the **inner** and **outer root sheaths.** Below the orifices of the sebaceous gland ducts the outer root sheath is formed by the stratum germinativum and stratum mucosum, while above them all the epidermal strata contribute to it. The inner root sheath surrounds the cuticle of the hair, and consists from without inwards of— (*a*) *Henle's layer,* a single stratum of nucleated, cubical cells; (*b*) *Huxley's layer,* a single or double layer of polyhedral nucleated cells; and (*c*) *a delicate cuticle,* consisting of a single layer of flattened

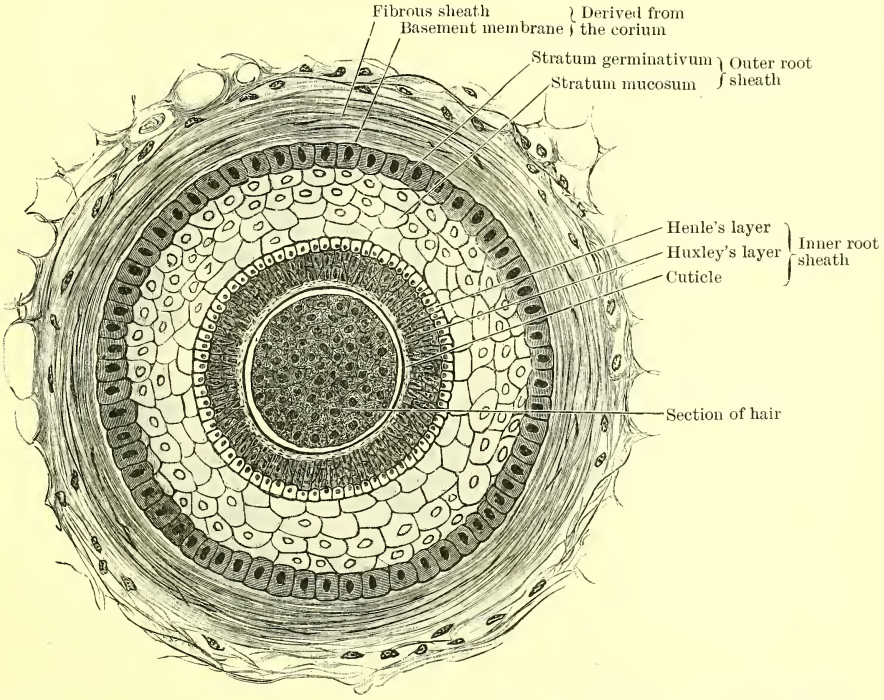


Fig. 609.—Transverse Section of Hair Follicle with contained Hair (highly magnified).

imbricated cells, with atrophied nuclei. The bottom of the hair follicle is indented by a vascular **papilla** (papilla pili), derived from the corium and capped by the bulb (bulbus pili) or expanded part of the hair root. The cells of the bulb are continuous with those of the outer root sheath, and form the different parts of the hair, as well as its inner root sheath. The vessels form capillary loops in the papilla of the hair, and send twigs into the outer layer of its fibrous sheath; the inner and outer root sheaths and the different parts of the hair are non-vascular. The nerves terminate in longitudinal and annular fibrils below the level of the sebaceous glands and outside the hyaline layer of the follicle.

Sebaceous glands (glandulæ sebaceæ) exist wherever there are hairs, and their ducts open into the superficial part of the hair follicles (Fig. 604); the number of glands associated with each follicle varies from one to four. On the labia minora and mammary areolæ they open on the surface of the skin independently of hair follicles, and in the latter situation undergo great enlargement during pregnancy. The deep extremity of each gland expands into a cluster of oval or flask-shaped **alveoli,** which are surrounded by a basement membrane, and filled with polyhedral cells containing oil droplets. By the breaking down of the superficial cells, their oily contents are liberated as the *sebum cutaneum* and discharged into the hair follicle, whilst the deeper cells undergo proliferation. The size of the gland bears

no proportion to that of the hairs, since they are very large in the minute hair follicles of the fœtus and newly born child, and also in the follicles of the rudimentary hairs of the nose and certain parts of the face.

Bundles of non-striped muscular fibre are associated with the hair follicles, and are named the **mm. arrectores pilorum**. Attached to the deep part of the hair follicle, and forming with it an acute angle, they pass outwards close to the sebaceous glands, to end in the papillary layer of the corium. Situated on the side of the hair towards which it slopes, they, on contraction, diminish the obliquity of the hair follicle and render the hair more erect, and, at the same time, compress the sebaceous glands and expel their contents. The condition of "goose-skin" is caused by the contraction of these slender muscles.

Thomson suggests that the condition of curly hair is produced by the contraction of these small muscles. Straight hair is thick and rounded; curly hair is flat and ribbon-like. When the erector muscle contracts, the thick rounded hair resists the tendency of the muscle to bend it, while the flat hair, not sufficiently strong to resist the strain of the muscle, becomes bent, and this is probably the explanation why the follicle assumes the curved form characteristic of the scalp of a bushman. The sebaceous gland lies in the concavity of the bend between the follicle and the muscle, and forms a mass of greater resistance, around which the follicle may be curved by the contraction of the muscle. The cells at the root of the hair accommodate themselves to the curved follicle, and, becoming more horny as they advance to the surface, retain the form of the follicle in which they are moulded.

The **sudoriparous** or **sweat glands** (glandulæ sudoriferæ) are relatively few in number on the back of the trunk, but are very plentiful on the palms and soles, where they open on the summits of the curved ridges. Each consists of an elongated tube, the deeper portion of which forms its secretory part, and is coiled in the subcutaneous tissue or deep part of the corium in the form of an ovoid or spherical ball, termed the **glomerulus** or **corpus glandulæ sudoriferæ** (Fig. 604). The superficial part of the tube, or **ductus sudoriferus**, extends through the corium and epidermis, and opens on the surface by a funnel-shaped orifice, the **porus sudoriferus**; where the epidermis is thick the duct is spirally coiled. The **glomeruli**, as a rule, vary in diameter from 0·1 to 0·5 mm., but in the axillæ they are much larger, and may measure from 1 to 4 mm. Each is surrounded by a capillary network and by a capsule of connective tissue, inside which is a homogeneous basement membrane. The lumen of the tube is lined by a layer of nucleated, granular, and striated, columnar, or prismatic epithelium, between the deep extremities of which and the basement membrane is a layer of non-striped muscular fibres, the long axis of which is more or less parallel with that of the tube. The excretory ducts are devoid of muscular fibres, and consist of a basement membrane lined by two or three layers of polyhedral cells, which are covered, next the lumen of the tube, by a thin cuticle.

The **glands of Moll** (glandulæ ciliares), opening at the margins of the eyelids, and the **glandulæ ceruminosæ** of the external auditory meatus, are modified sudoriparous glands; the former are, however, not coiled up to form glomeruli, while the cell protoplasm of the latter contains yellowish pigment, and their gland ducts, in the fœtus, open into hair follicles.

Development of the Skin and its Appendages.

Skin.—The vascular and sensitive corium is developed from the mesoderm, the cells of which, immediately underlying the ectoderm, have, by the second month of fœtal life, become aggregated together and flattened parallel to the surface of the embryo. By the third month they are seen to form two layers, the superficial of which becomes the corium, and the deeper the subcutaneous tissue; the papillæ of the corium make their appearance in the fourth month. The epidermis, nails, hairs, sweat and sebaceous glands are all of ectodermal origin.

The epidermis at first consists of a single layer of cells, but by the end of the second month it is duplicated, and then exhibits a superficial layer of irregular cells and a deeper layer of more or less cubical cells. By the third month three strata are seen: (*a*) a deep layer, consisting of a single stratum of cubical cells—the future stratum germinativum; (*b*) a middle layer, comprising two or three strata of irregular cells—the future stratum

mucosum; and (*c*) an outer layer, a double stratum of large cells. This outer layer appears to be homologous with a thin membrane, termed the *epitrichium*, first described as covering the embryo of the sloth and overlying its hairs, but since shown to be present in birds and mammals. Over the hairy parts of the body it disappears about the sixth month; but over the free edge and root of the nails, and on the palms and soles, it develops into several layers of cells, which, in these parts, probably persist to form the thick stratum corneum. The part which persists over the root of the nail is termed the *eponychium*, and covers the proximal part of the lunula (*vide* p. 776). The stratum lucidum is differentiated from the cells of the epitrichium, and, where the latter is lost, possibly forms the superficial layer of the epidermis as it does the horny part of the nails.

Nails.—The first rudiment of the nails is seen about the beginning of the third month of embryonic life, and consists of a thickening of the epitrichium over the extremity of the digits. Owing to the growth of the palmar aspect of the digits, the nail rudiment comes to be placed dorsally, and, at its proximal edge, an ingrowth of the stratum mucosum occurs to form its root, while the future nail becomes limited behind and laterally by a groove. The superficial cells of the stratum mucosum become keratinised to form a thick stratum lucidum, the future nail proper, over the greater part of which the epitrichium disappears. The latter persists in the adult as the perionyx across the root of the nail, and, until fifth month, also forms a thick mass over the extremity of the nail, and is continued into the stratum corneum over the end of the digit. The future distal edge of the nail, at this stage, is continuous with the stratum lucidum in front of it; but this continuity is lost, and by the seventh month the nail presents a free border. The nails grow in length, and are renewed, in case of removal, by a proliferation of the cells of the stratum mucosum at the root of the nail, while an increase in their thickness takes place from the part of the same stratum which underlies the lunula.

Hairs.—The hair rudiments appear about the third month of embryonic life as solid downgrowths of the stratum mucosum, which pass obliquely into the subjacent corium. The deep end of this column of cells becomes expanded to form the hair bulb, and rests on a papilla derived from the corium, the epidermis immediately overlying which becomes differentiated into the hair and its inner root sheath, while the peripheral cells form its outer root sheath. The surrounding corium becomes condensed to form the fibrous sheath of the hair follicle, the hyaline layer of which is continuous with the basement membrane covering the corium. The hair gradually elongates, and, reaching the neck of the follicle, its extremity lies at first under the epitrichium, but becomes free on the disappearance of the latter. This takes place about the fifth month, and the first crop of hairs constitutes the *lanugo*, which is well developed by the seventh month. The lanugo consists of very delicate hairs, some of which are shed before, the remainder shortly after birth—the last to drop out being those of the eyelashes and scalp—and are replaced by stronger hairs. Shedding and renewal of the hairs take place during life, the renewal being, of course, absent in the case of baldness. Prior to the shedding of a hair active growth and proliferation of the cells of the hair bulb cease, and the papilla becomes atrophied, while the hair root, gradually approaching the surface, at last drops out. New hairs arise from epidermic buds, which extend downwards from the follicle, and their development is identical with that of the original hairs.

Sebaceous Glands.—These appear about the fifth month as solid outgrowths from the sides of the hair follicles, and consist of epidermal offshoots continued from the cells of the outer root sheath. Their deep ends become enlarged and lobulated, to form the secreting part of the gland, while the narrow neck connecting this with the follicle forms its duct. The sebaceous secretion, together with the cast-off epidermal cells, is collected on the surface of the body during the last months of intrauterine life, and forms a layer of varying thickness, termed the *vernix caseosa* or *smegma embryonum*.

Sweat Glands.—These, like the hairs, arise as solid downgrowths of the stratum mucosum. They descend, however, perpendicularly, instead of obliquely, and are of a yellowish colour; they appear on the palms and soles early in the fifth month, but much later over the hairy parts of the body. The downgrowths extend through the corium, and, on reaching the subcutaneous tissue, become coiled up to form the secreting part of the gland. The lumen of the gland does not open on the surface until the seventh month.

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